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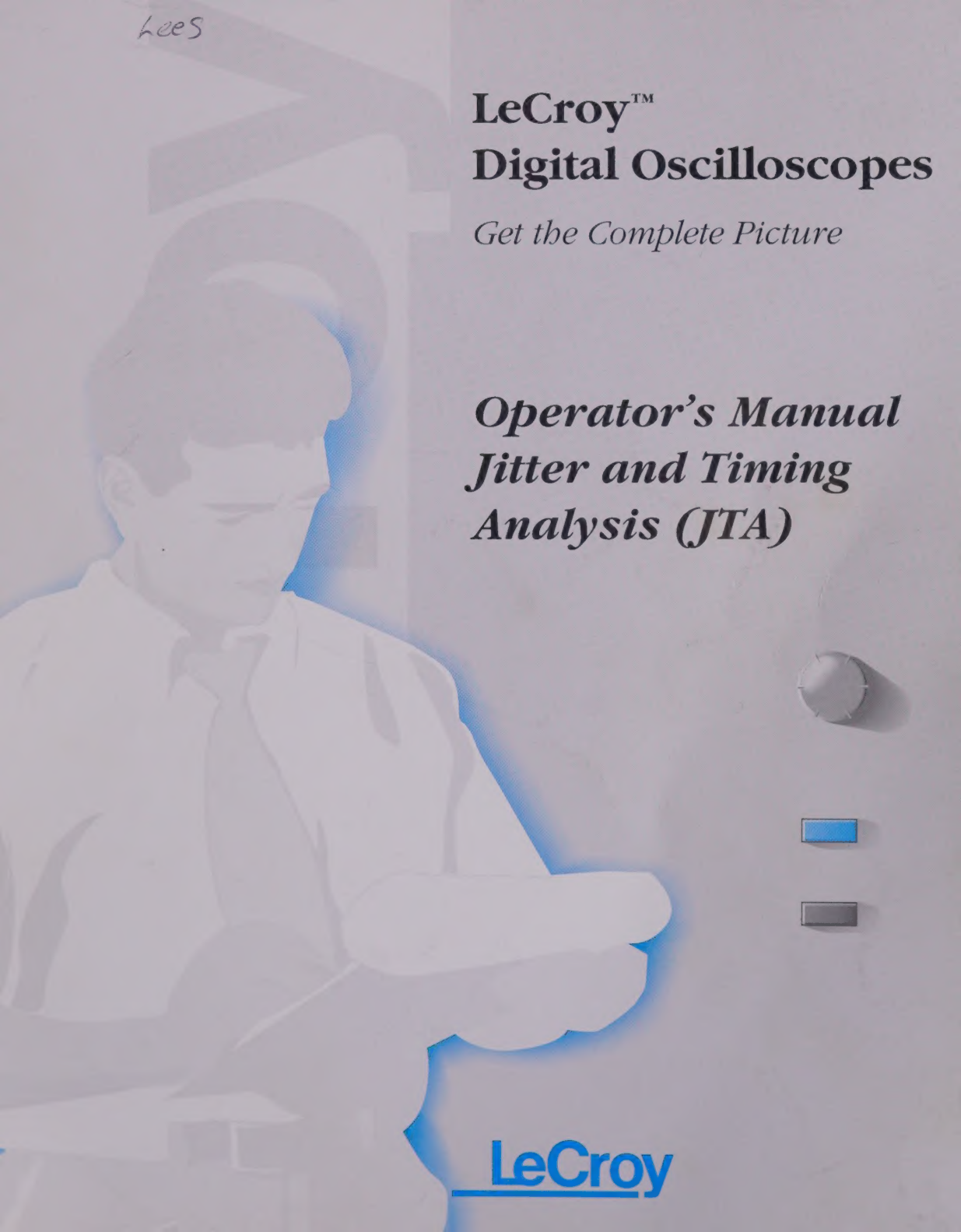
LeCroy™ Digital Oscilloscopes

Get the Complete Picture

Operator's Manual Jitter and Timing Analysis (JTA)



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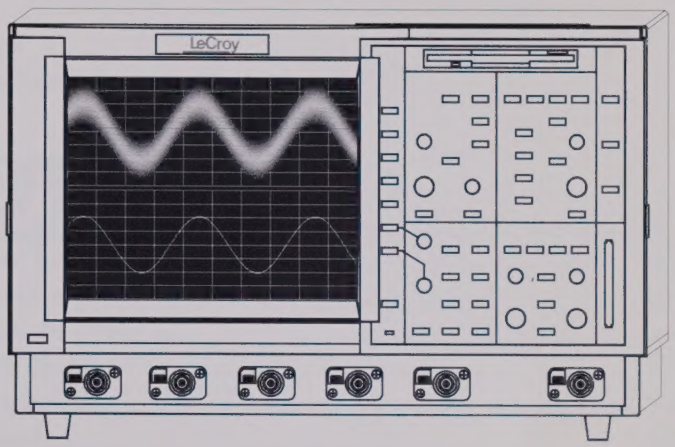

Operator's Manual

Jitter & Timing Analysis (JTA) for LeCroy Digital Oscilloscopes

Revision A — March 1998

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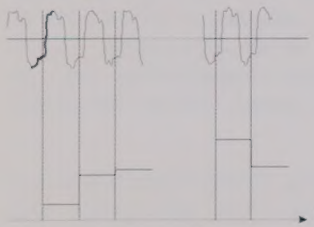
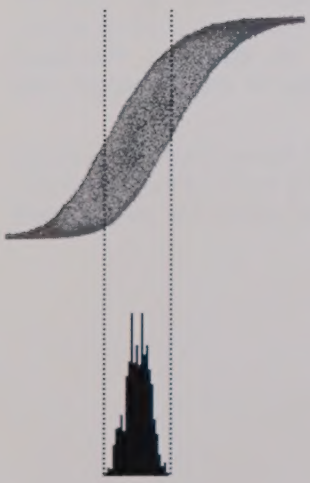
The Tools and the Work They Do

The Jitter & Timing Analysis package (JTA), added to your LeCroy digital oscilloscope, contains the essential tools for timing and jitter measurements. This special software augments LeCroy's long memory and highly accurate clock to make the most common of such measurements easier and more precise. And make possible new approaches.

JTA has three sets of tools: Timing Functions, Timing Parameters and Statistical Tools.

Timing Functions





The first of these consists of JitterTrack, Persistence Histogram and Persistence Trace functions.

- **JitterTrack** graphically plots as a function of time the amplitude of the waveform attributes *Cycle–to–Cycle* variation, *Duty Cycle*, *Interval Error*, *Period* and *Width*.

  Interval Error — for example — calculates the timing error of a signal compared with an "ideal", expected "interval" defined by a user-specified reference frequency, the most common estimator of jitter. Plotted are "the short-term variations of a digital signal's significant instants, from their ideal positions in time."* This is the perfect tool for characterizing clocks in synchronized Telecom networks such as SONET and SDH. *See Chapter 2.*

- **Persistence Histogram** analyzes a vertical or horizontal "slice" of a persistence map of multiple waveforms. The resultant bar chart shows a numerical measurement of the timing variations of a signal, which are observed qualitatively in the persistence display of the signal. A typical application is characterizing the jitter in a communications-signal eye diagram. *See Chapter 3.*

- **Persistence Trace** is a new concept for displaying the data acquired from multiple sweeps of a waveform. A vector trace is computed, based on the bit map of the underlying multiple signal acquisitions. Detail is then represented in a choice of

* As defined in Bellcore TR-499.

three graphic forms, each representing a different characteristic of the waveform. Insight into edge details is given down to a few picoseconds, valuable in applications such as the examination of fast-signal transitions. *See Chapter 4.*

Timing Parameters

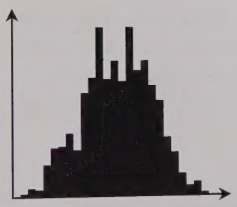
JTA's Timing Parameters, too, can be used for measuring cycle–to–cycle jitter, the width of positive and negative pulses, the duty cycle of either polarity, and an infinite number of cycles on long records. Pulses or cycles can be counted using one of these parameters.

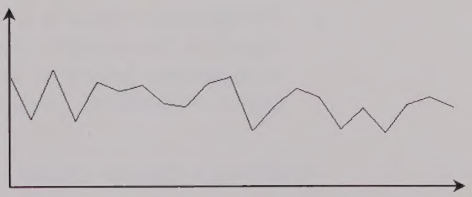
Applying interpolation filtering to signal edges in the vicinity of measurement points, Timing Parameters operate on acquired waveform levels that may be selected in either volts or percentages of signal amplitude. Each parameter calculation is performed over all cycles or edges present in the input signal, without limitations. *See Chapter 5.*

Statistical Tools

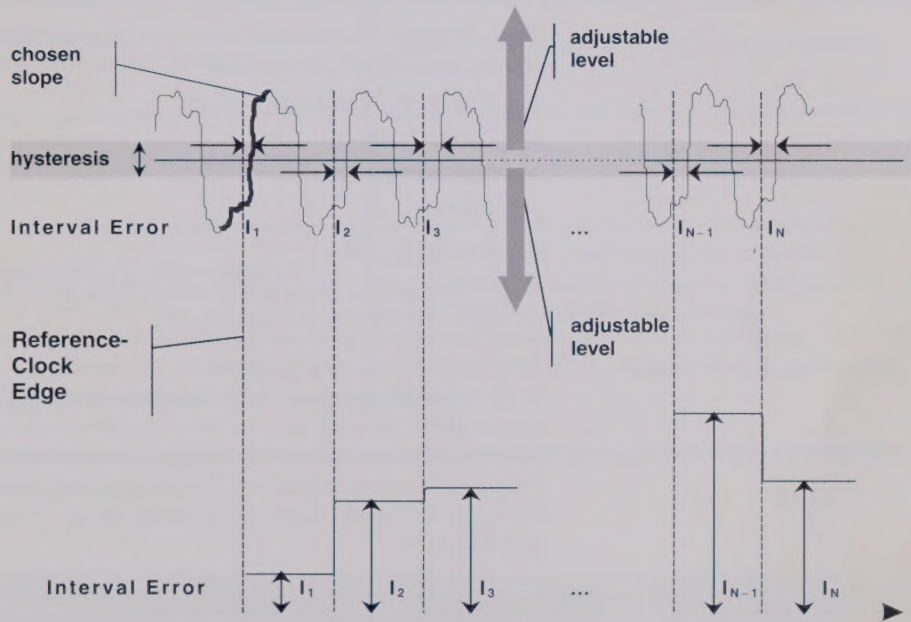
The information obtained from applying Timing Parameters can then be analyzed using the Statistical Tools: Histograms and Trends.

- **Histograms** characterize and present as a bar chart the statistical distribution of a Timing Parameter's set of values. In addition to this, there are 18 statistical, Histogram Parameters, which operate directly on the histogram. *See Chapter 6.*
- **Trends** represent the evolution of Timing Parameters in line graphs whose vertical axes are the value of the parameter, and horizontal axes the order in which the values were acquired. *See Chapter 7*





How JitterTrack Tracks Down Jitter



- *Illustrated here*: the *Interval Error* JitterTrack Function. Use this function to plot as a bar chart the evolution over time of signal attributes.
- Set the desired reference clock frequency for an "ideal" position against which the signal is to be compared.
- Specify the level at which the jitter measurement is to be made, as well as the rising or falling edge on which the measurement is to start.
- Set hysteresis, a voltage band that extends above and below the selected level, whose limits must be crossed by the signal for that signal to be considered valid.
- Timing errors are graphically revealed.

When to Use JitterTrack

The JitterTrack Function charts the evolution in time of these waveform attributes:

- ***Cycle–to–Cycle* deviation**
- ***Duty Cycle***
- ***Interval Error***
- ***Period***
- **Pulse *Width.***

Each is time-correlated to its source trace and contains the same number of points as the waveform.

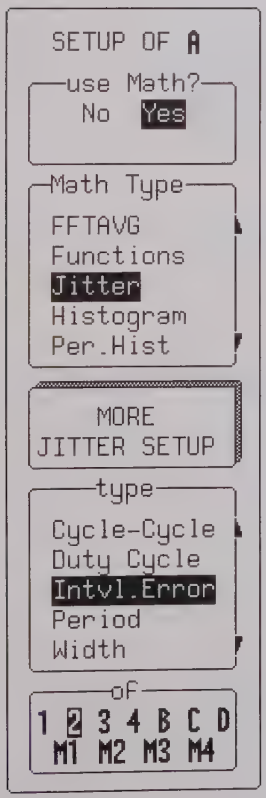
JitterTrack or Trend?

Whether it is more appropriate to use JitterTrack or the Statistical Tool, Trend (*described in Chapter 7*), will largely depend on the application, as well as the other factors set out in the tables below. Whereas JitterTrack sample points are evenly spaced in time, those of Trend are not. Trend plots any parameter available in the oscilloscope against its event count, as in a scatter or an XY diagram.

Characteristic	Trend	JitterTrack
Representation	parameter value vs. events	attribute value vs. time
Attributes or Parameters Supported	All Parameters (*see Appendix D of the scope Operator's Manual for a complete list and description*)	*Cycle–Cycle* *Period* *Duty Cycle* *Width* *Interval Error*
Behavior	Cumulative over several acquisitions up to 20 000 events	Non-cumulative (resets after every acquisition) Unlimited number of events

When you need to...	Use...
Monitor the evolution of a waveform parameter or attribute over several acquisitions...	***Trend*** — Jitter works only on one acquisition at a time.
Time-correlate an event and a parameter value...	***JitterTrack.***
Monitor an evolution in the frequency domain...	***JitterTrack*** — Trend points are not evenly spaced in time and therefore cannot be used for FFT (Fast Fourier Transform).
Monitor non-JTA parameters...	***Trend.***

Set Up and Configure for JitterTrack



1. **Press** MATH SETUP **to display the ZOOM + MATH menus. They allow redefinition of any of the four traces, A, B, C and D and access their "SETUP" menus.**
2. Press the for "REDEFINE **A**", to configure the function — on Trace A for this example.
3. Select "Jitter" from the "Math Type" menu and use the menus shown here to configure any of the five JitterTrack types *described on the pages that follow.*

use Math?

To choose a math function.

Math Type

For selecting "**Jitter**".

MORE JITTER SETUP

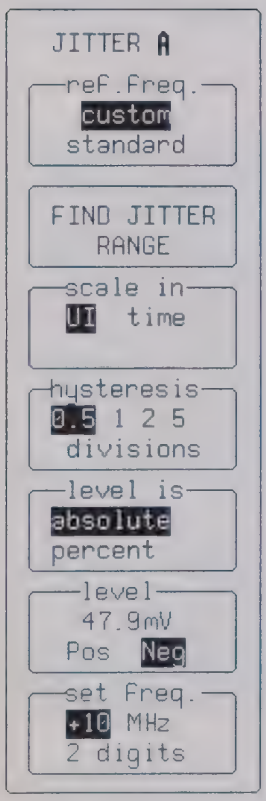
To access the "JITTER A" secondary menu (*next page*).

type

For selecting one of the five types of JitterTrack.

of

For selecting the source trace (*four-channel menu shown*).



ref. freq. *(INTERVAL ERROR ONLY)*

Enables the choice for the reference clock of either a "**custom**", user-defined frequency, or selection from a list of "**standard**", pre-defined frequencies. The frequency is adjusted using the "set freq." menu (*see below*).

FIND JITTER RANGE

Scales JitterTrack automatically once calculated.

scale in *(INTERVAL ERROR ONLY)*

Expresses the attribute in either "**UI**" unit intervals or seconds ("**time**").

hysteresis

Defines the hysteresis, in divisions. A voltage band is extended equidistantly above and below the selected level. In order for the signal to be considered valid, and not as noise, the signal must exceed, or cross, the upper or lower limits of this band by half the hysteresis-division setting.

level is

Determines whether the levels should be set in "**absolute**" — in volts — or as a "**percent**"-age of signal amplitude.

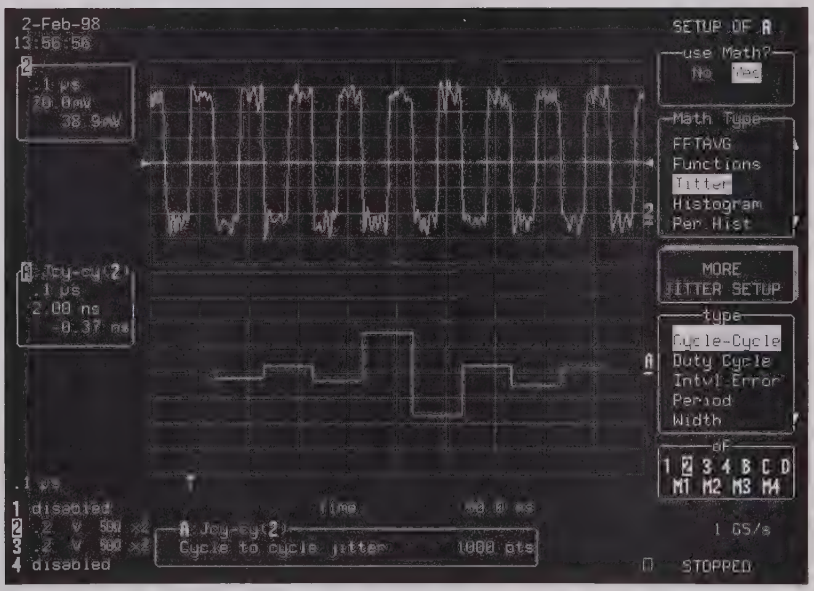
level

For selecting the voltage or amplitude-percentage setting of the level on the waveform at which the timing is to be measured. And to select whether the measurement should be made on a "**Pos**"-itive (rising) edge, or a "**Neg**"-ative (falling) edge.

Set freq. *(INTERVAL ERROR ONLY)*

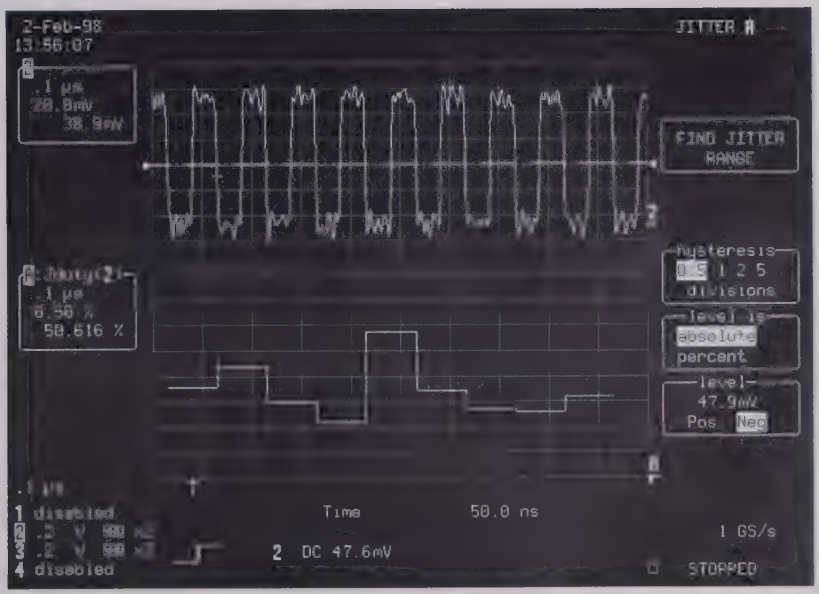
When "**custom**" has been chosen from the "ref. freq." menu, a particular user-defined frequency can be selected. The corresponding button for this menu highlights the mantissa (the exponent or the number of digits), while the associated knob changes the value highlighted. When "**standard**" has been chosen, selection from a number of pre-defined frequencies can be made for the reference clock, using the menu button.

Cycle–Cycle



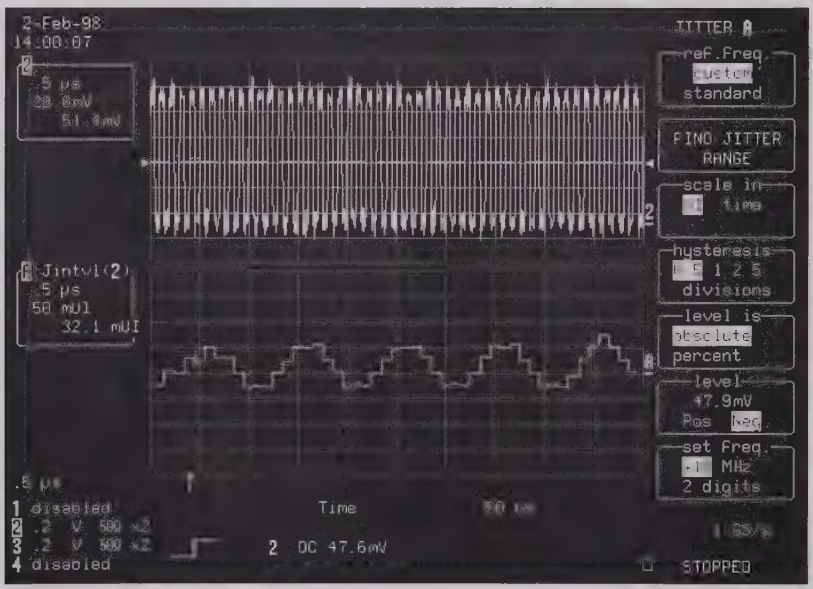
Cycle–Cycle JitterTrack Function: charts the differences in consecutive cycles across the waveform. Note the cross-hair time cursor on the falling edge of the second pulse from the left on the signal, and — at the same position in time — on the bar chart on Trace A. As cycle difference *is involved, the measurement starts on Cycle 2 (CC1 = C2 – C1). Note also the information contained, as with other oscilloscope traces, in the Displayed Trace Fields for both the signal and Trace A: timebase, amplitude and cursor value. The time cursor position, too, is indicated by the arrow and value (50 ns) below the grid.*

Duty Cycle



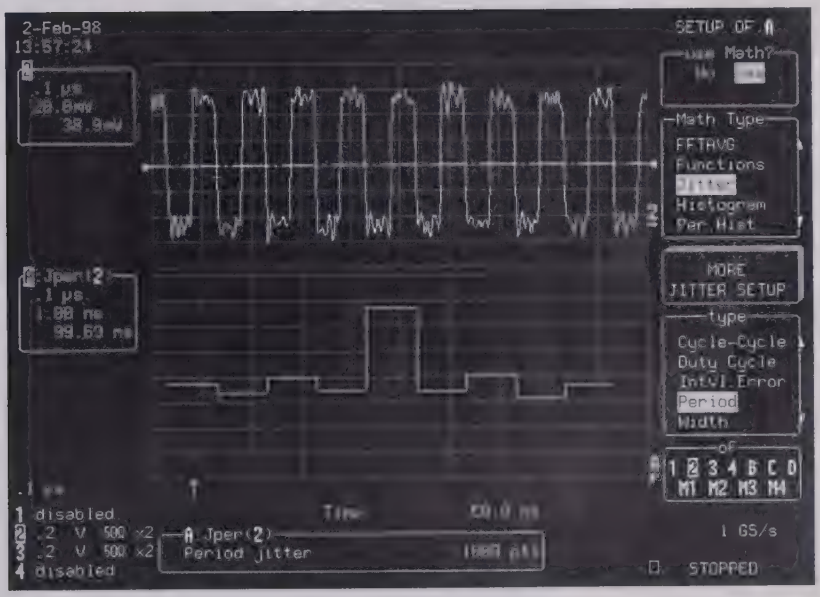
Duty Cycle JitterTrack Function: charts consecutive duty cycles across the waveform. Level, slope and hysteresis are specified. Note the cross-hair time cursor on the falling edge of the second pulse from the left on the signal trace, and — at the same position in time — on the bar chart on Trace A. Note also the information contained, as with other oscilloscope traces, in the Displayed Trace Fields for both the signal and Trace A: timebase, amplitude and cursor value. The time cursor position, too, is indicated by the arrow and value (50 ns) below the grid.

Interval Error



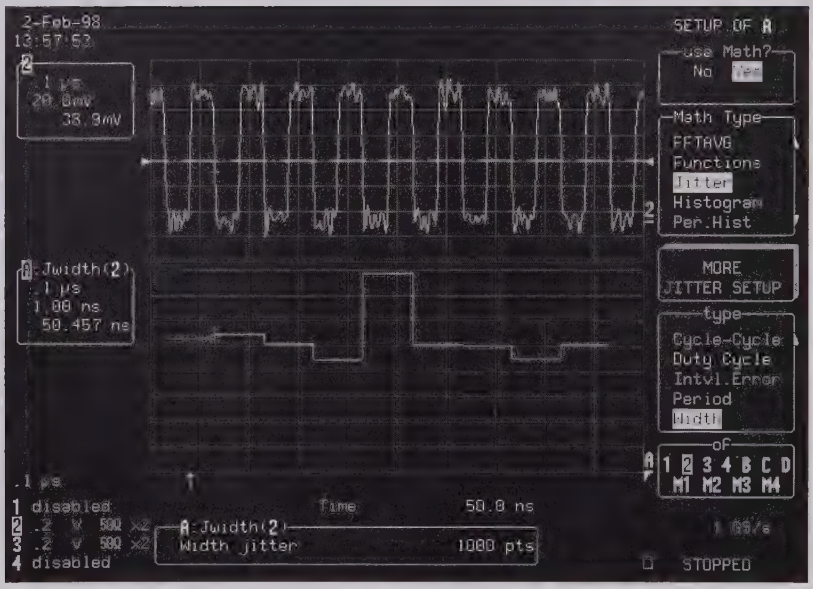
Interval Error JitterTrack Function: charts the timing errors across the waveform by comparing the signal with a user-selected reference. A "custom" reference frequency of 10 Mhz has been chosen here, and level, slope and hysteresis are specified, too. Note the cross-hair time cursor on the signal trace and — at the same position in time — on the bar chart on Trace A. Note also the information contained, as with other oscilloscope traces, in the Displayed Trace Fields for both the signal and Trace A: timebase, amplitude and cursor value. The time cursor position, too, is indicated by the arrow and value (50 ns) below the grid.

Period



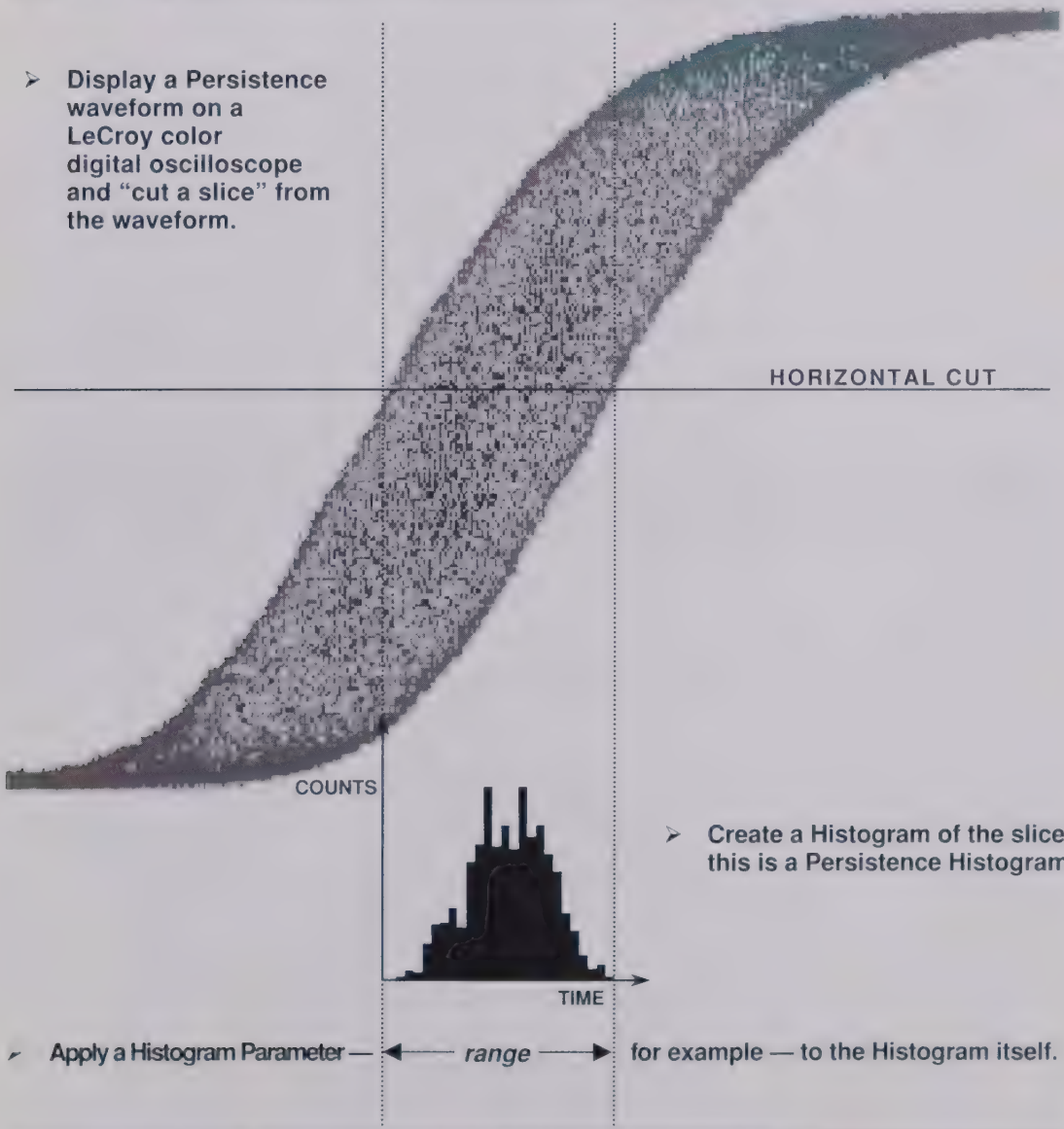
Period JitterTrack Function: charts the differences in consecutive periods across the waveform. Note the cross-hair time cursor on the signal trace and — at the same position in time — on Trace A. Note also the information contained, as with other oscilloscope traces, in the Displayed Trace Fields for both the signal and Trace A: timebase, amplitude and cursor value. The time cursor position, too, is indicated by the arrow and value (50 ns) below the grid.

Width



Width JitterTrack Function: charts the differences in consecutive pulse widths across the waveform. Note the cross-hair time cursor on the signal trace and — at the same position in time — on Trace A. And the number of sample points used by the measurement indicated in the field beneath the grid. Note also the information contained, as with other oscilloscope traces, in the Displayed Trace Fields for both the signal and Trace A: timebase, amplitude and cursor value. The time cursor position, too, is indicated by the arrow and value (50 ns) below the grid.

How "Per. Hist" Reveals Hidden Features


➢ Display a Persistence waveform on a LeCroy color digital oscilloscope and "cut a slice" from the waveform.
HORIZONTAL CUT
COUNTS
TIME
➢ Create a Histogram of the slice: this is a Persistence Histogram.
➢ Apply a Histogram Parameter — range — for example — to the Histogram itself.

Why *Persistence* Histograms and When?

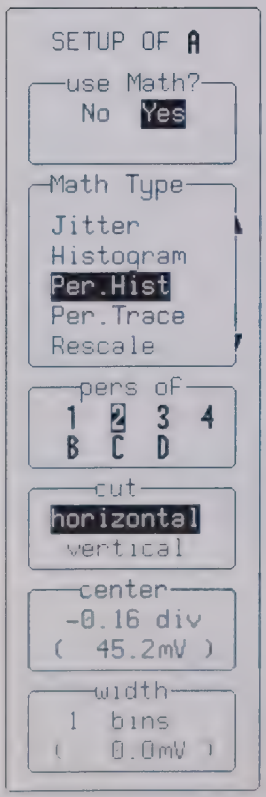
The Persistence Histogram Function, Per.Hist, builds the histogram from a persistence map* to reveal the features that only exist when several acquisitions have been superimposed on one another. In contrast to this, the Histogram as Statistical Tool (*see Chapter 6*) simply graphs waveform parameters such as amplitude, frequency or pulse width on an acquisition or series of acquisitions.

Both Histogram and Persistence Histogram bar charts are divided into intervals, or bins. But whereas each bin in the Histogram bar chart contains a class of similar parameter values, Per.Hist analyzes both vertical and horizontal "slices" of the persistence map. Vertically, each bin contains a class of similar *amplitude* levels; horizontally, a class of similar *time* values.

For a Histogram of...	Use...
A crossover point in time or in amplitude on an eye diagram...	**Per.Hist.** (Vert. *and* Horiz. Slices)
Cumulative jitter on an eye diagram...	**Per.Hist** (Horiz. Slice)
Signal-to-noise ratio on an eye diagram... ...	**Per.Hist.** (Vert. Slice)
The different interval widths present in a long data stream...	**Histogram** (of Timing Parameter *p@lv*)
Cumulative jitter on a long record of a clock signal	**Histogram** (of Timing Parameter *tie@lv*)
Cycle-to-cycle jitter	**Histogram** (of *Δp@lv*)

* Persistence maps are generated using the Persistence function on LeCroy color digital oscilloscopes.

Set Up and Configure for Per.Hist



1. **Acquire a trace in Persistence mode, using LeCroy Analog Persistence™ or Color-Graded persistence (*see the color digital oscilloscope Operator's Manual*).**

2. Press MATH SETUP to display the ZOOM + MATH menus. They allow redefinition of any of the four traces, A, B, C and D and access their "SETUP" menus.

3. Press the for "REDEFINE **A**", to configure the function — on Trace A for this example. Then select "**Per.Hist**" from the "Math Type" menu and use the menus shown here to create a Persistence Histogram.

use Math?

To choose a math function.

Math Type

For selecting "**Per.Hist**".

pers of

For selecting the source trace to be histogrammed.

cut

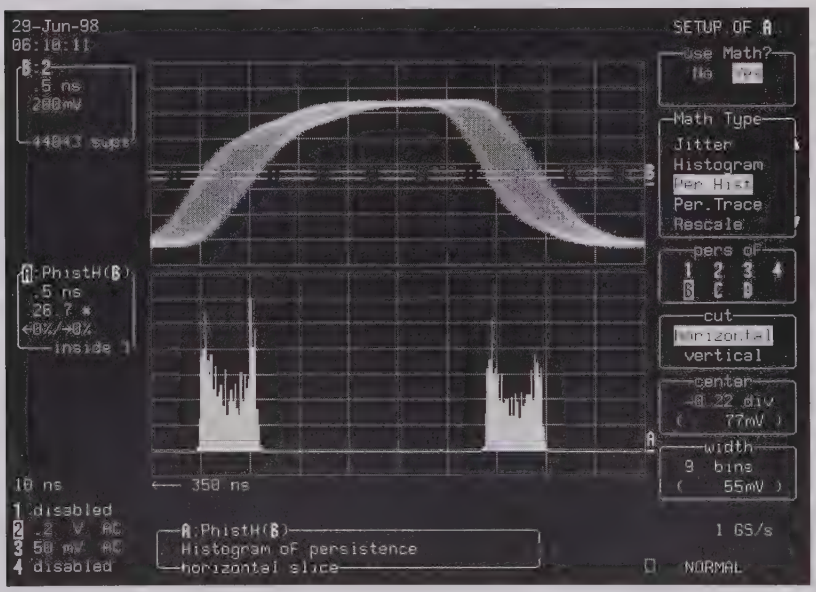
To select to cut a horizontal or vertical slice of the persistence waveform for histogramming. Here, "**horizontal**" has been selected, which means that the parenthesized values set in the "center" and "Width" menus. *below*, will be expressed in units of amplitude. When "**vertical**" is highlighted, the same values will be expressed in units of time, and in pixels.)

Center

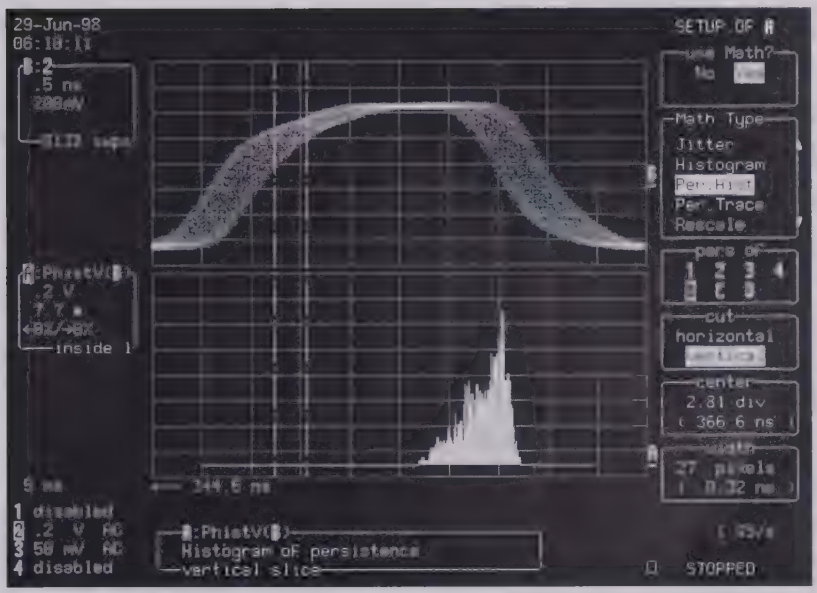
To position the cut on the persistence waveform: a pair of dedicated line cursors appear for visualizing and positioning the "slice", controlled with the corresponding menu knob. Pressing the menu button causes the cursor to revert to the middle of the grid.

Width

To set the width of the "slice": a pair of dedicated line cursors appear for visualizing and setting the width of the cut, controlled using the corresponding menu knob. The menu button causes the width to revert to zero. (The "bins" referred to in this menu when horizontal cuts are made are *not* histogram bins, but rather eight-bit ADC bins.)

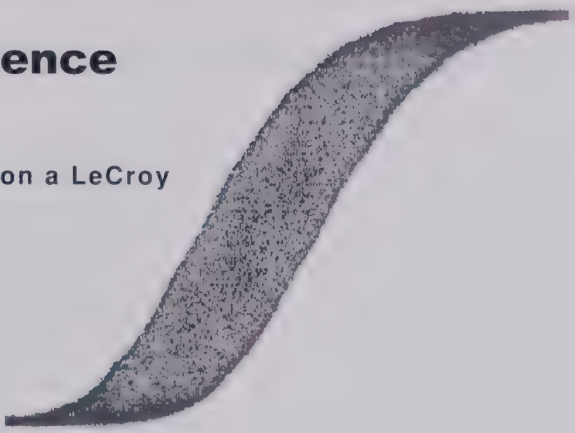


Persistence Histogram, horizontal cut. The horizontal "slice" has been "cut" using the cursors set with the center and width menus. Note the exact alignment of the bar chart sections on Trace A with the sliced Persistence waveform region on each occasion that the cursors intersect the waveform. The Per.Hist Function may be further analyzed using either the oscilloscope's standard measurement cursors or Histogram Parameters.



Persistence Histogram, vertical cut. The "slice" has been "cut" using the cursors set with the center and width menus. With vertical cuts, the bar chart on Trace A is unaligned with the slice of the Persistence waveform (this is because low-amplitude bins are displayed at left, and high-voltage bins at right, of the grid). The Per.Hist Function may be further analyzed using either the oscilloscope's standard measurement cursors or Histogram Parameters.

How to Trace Persistence



- Display a Persistence waveform on a LeCroy color digital oscilloscope.

- From this waveform, create any of three types of shapes on which waveform processing can be performed.

Average *Range* *Sigma*

An Innovative Visual AND Processing Tool

Persistence Trace (Per.Trace) empowers the oscilloscope's Persistence display. With this Timing Function, not only can waveform noise and jitter be visualized, but further processing can be done — previously not possible with Persistence alone.

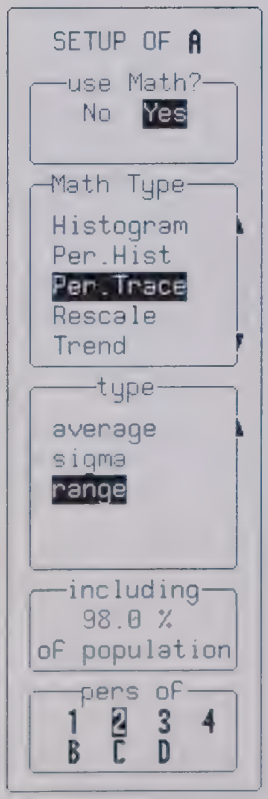
Per.Trace generates special graphic representations of the Persistence waveform on which further processing, such as the application of parameters and even PASS/FAIL testing, can be performed.

Displaying data acquired from multiple sweeps of the waveform, Per.Trace computes a vector trace based on the bit map of the underlying signal acquisitions. Detail is then shown in a choice of three shapes (*illustrated on the previous page*): "average", "sigma" and "range". These are created without destroying the underlying data, allowing visualization of analytical results from observation of raw data.

Typical applications and which of the three Per.Trace types to use for them are given in the table.

To...	Use Per.Trace...
See edge detail in a fast signal	*average*
Eliminate noise on a persistence trace	*average*
Assess "typical" noise on a persistence trace	*sigma*
Assess "worst case" noise on a persistence trace, and use it to create a tolerance mask	*range*

Set Up and Configure for Per.Trace



1. **Acquire a trace in Persistence mode, using Analog Persistence™ or Color-Graded persistence (*see the color digital oscilloscope Operator's Manual*).**

2. Press MATH SETUP to display the ZOOM + MATH menus. They allow redefinition of any of the four traces, A, B, C and D and access their "SETUP" menus.

3. Press the for "REDEFINE **A**", to configure the function — on Trace A for this example. Then select "**Per.Trace**" from the "Math Type" menu and use the menus shown here to create a Persistence Trace.

use Math?

To choose a math function.

Math Type

For selecting "**Per.Trace**".

type

To select the type of Persistence Trace: "**average**", "**sigma**" or "**range**".

including/scale to

When "**range**" is selected, as in this example, a percentage of the population of the persistence map can be chosen from which the envelope will be formed, enabling exclusion of infrequent events (artifacts).

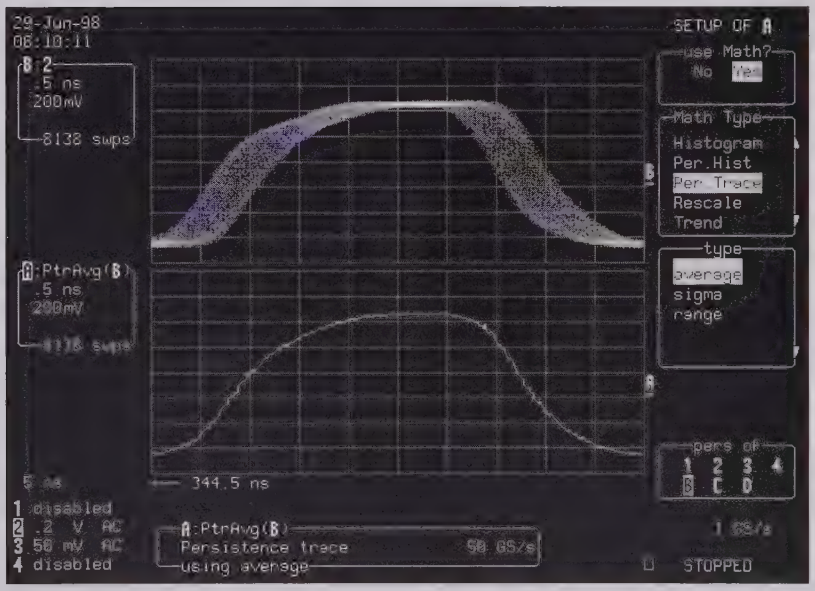
When "**sigma**" is highlighted, this becomes the "scale to" menu, which allows selection of a sigma factor of from 0.5–10.0. Expands those parts of the sigma envelope representing waveform regions with the most jitter.

When "**average**" is selected, this menu does not appear at all.

pers of

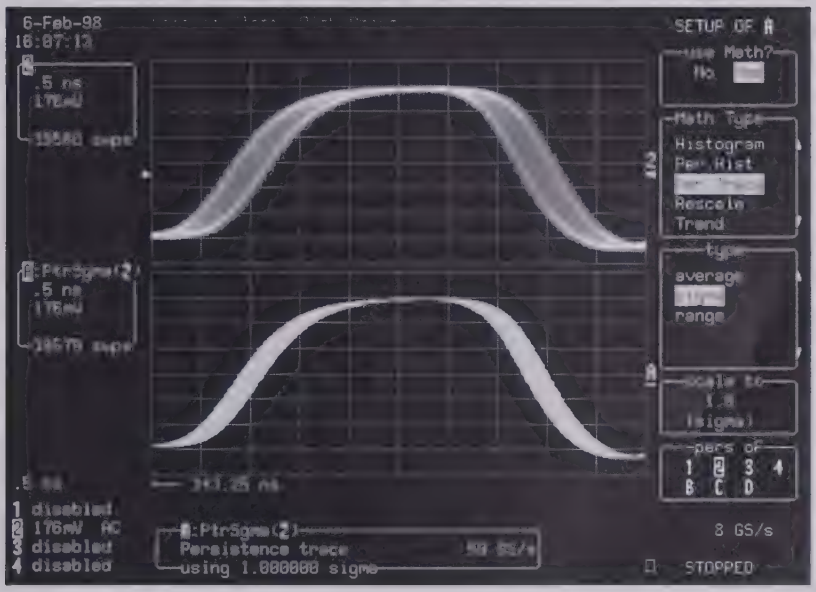
For selecting the source trace to which the Persistence Trace Function is to be applied.

average



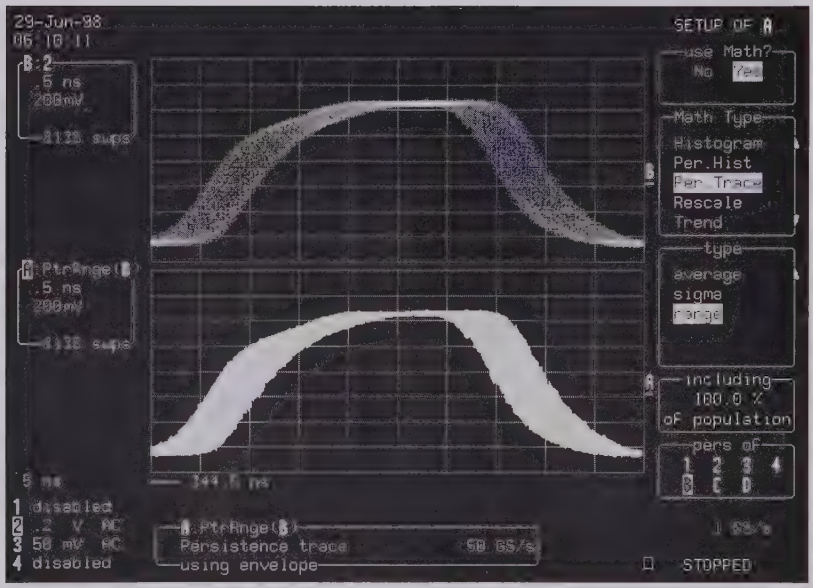
Persistence Trace: average. For each vertical time slice on the persistence map, calculates and plots a trace corresponding to the map's mean value. Single-shot signals sampled at or above 2 GS/s and accumulated in the persistence map can be traced at a resolution of 10 ps (100 GS/s equivalent sampling). The Per.Trace average may be further analyzed using the oscilloscope's standard parameters such as rise time.

sigma



Persistence Trace: sigma. For each vertical time slice on the persistence map, calculates and plots an envelope corresponding to the map's standard deviation. Multiples of sigma can also be done using sigma.

range



Persistence Trace: range. For each vertical time slice on the persistence map, calculates and plots an envelope corresponding to the map's range. The Per.Trace range can then be used in further processing: for example, as a source for Pass/Fail masks.

Choosing a Timing Parameter

***Each JTA parameter** operates on level of the acquired waveform able to be selected either in volts or a percentage of signal amplitude.*

Each parameter calculation is performed over all cycles or edges present in the input signal, without limitation. The acquired set can then be analyzed using Histograms or Trends (see Chapters 6 & 7).

Advanced interpolation filtering is applied to the signal edges in the vicinity of the measurement points to optimize measurement accuracy, repeatability and speed.

Like the oscilloscope's other parameters, JTA Timing Parameters perform waveform measurements automatically. They, too, are applied and adjusted using on-screen menus, accessed by these steps[*]:

1. Press CURSORS/ MEASURE
2. Select "**Parameters**" from the top-most menu. The special Parameters grid will be displayed and the "MEASURE" menus appear.
3. Scroll through the "mode" menu and choose "**Custom**". In the "Statistics" menu below this, "**On**" can be selected to display each parameter's *average, low, high,* and *sigma* values.
4. Press the menu button for "CHANGE PARAMETERS". *(See page 5–3.)*
5. From the "Category" menu, select "**JTA**". The Timing Parameters will then appear as a group in the "measure" menu.
6. Choose the desired parameter, which will be highlighted both on the "measure" menu and beneath the grid. Up to five parameters can be selected for display, each shown on its own line below the grid. Other kinds of parameters can also be selected from these menus: Histogram Parameters from the "Statistics" category *(see next chapter).*

[*] *See the "CURSORS MEASURE and Parameters" chapter of the oscilloscope Operator's Manual for more on parameters.*

Which Parameter?

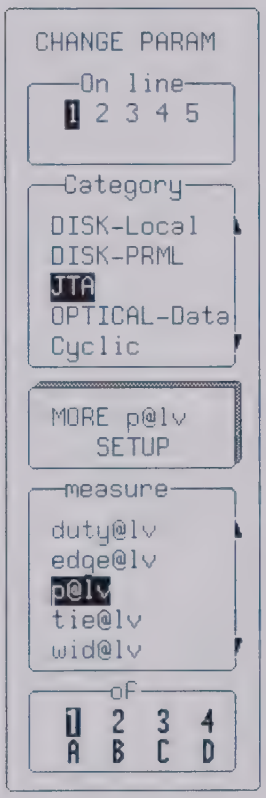
This table lists the JTA Timing Parameters (*second column from left*) and offers hints on the tasks they can perform. Additional analysis and processing of the waveform can be carried out by activating "Statistics" and using Histogram parameters (*as described on the previous page*). Finally, one of the variants of JitterTrack, (*see Chapter 2*) might serve as an alternative for the same task.

When you need to...	use Timing Parameter...	and for further processing...	Or use JitterTrack Function...
Measure clock or period accuracy...	p@lv	"Statistics" "**On**" *(see previous page)* or use Histogram *(see Chapter 6).*	***Period Jitter*** *(see Chapter 2).*
Measure pulse width accuracy...	wid@lv	"Statistics" "**On**" or use Histogram.	***Width Jitter*** *(see Chapter 2).*
Measure adjacent cycle deviation...	Δp@lv	"Statistics" "**On**" or use Histogram.	***Cycle–to–Cycle Jitter*** *(see Chapter 2).*
Count the number of edges in a waveform...	edge@lv	—	—
Measure duty cycle...	duty@lv	"Statistics" "**On**" or use Histogram.	***Duty Cycle Jitter*** *(see Chapter 2).*
Measure Time Interval Error...	tie@lv	Turn "Statistics" "**On**" or use Histogram.	***Interval Error Jitter*** *(see Chapter 2).*

A description of each Timing Parameter and the menus used for applying it starts next page.

p@lv — period at level

Calculates the period of each cycle in an acquired waveform.



On line

Selects for modification as many as five different parameters, each placed on its own line: "**1**", "**2**", "**3**", "**4**" or "**5**".

Category

Specifies the category of parameter. When "**JTA**" is selected, the "measure" menu (*below*) will feature the JTA Timing Parameters.

MORE p@lv SETUP

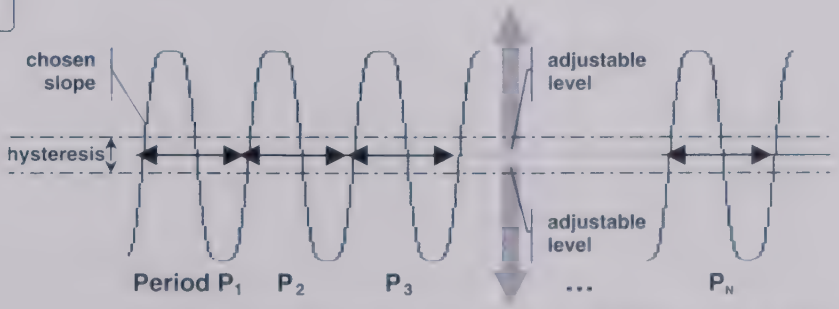
Primary menu that calls up the secondary "SETUP p@lv" menus (*next page*).

measure

For choosing the parameter to be measured on the selected line.

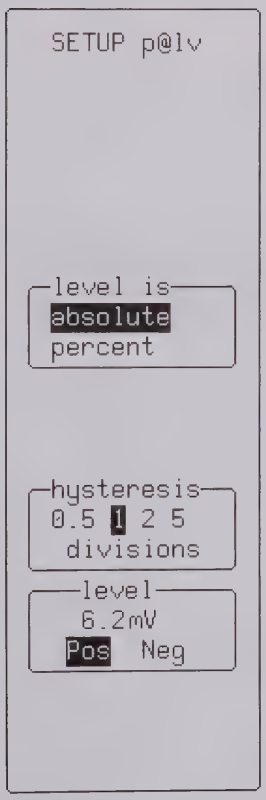
of

Selects the channel or trace on which the parameter will be measured (*four-channel menu shown*).



p@lv: measures the period of all cycles in the waveform; level, slope and hysteresis are specified by the user.

SETUP p@lv



The menu group shown here is used to set up all the Timing Parameters but *tie@lv* (*see page 5–9*). Selected is the level on the pulse at which the measurement will be made, as well as the value in which the level is to be expressed: V or %. Also enabled is the choice of whether the measurement will be made at a positive or negative edge. The threshold of the hysteresis band is also defined.

level is

Determines whether the levels should be set in absolute — in volts — or as a percentage of signal amplitude.

hysteresis

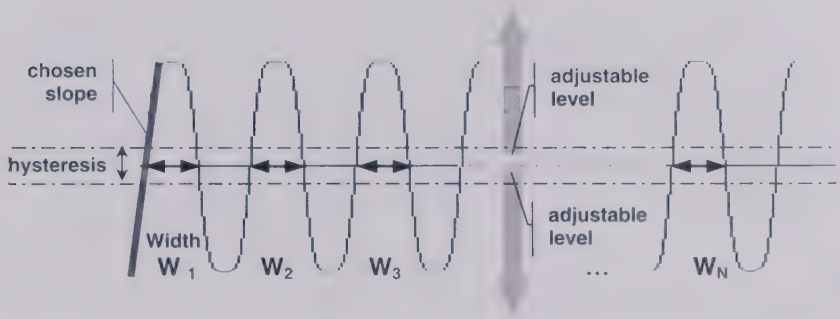
Defines the hysteresis, in divisions. A voltage band is extended equidistantly above and below the selected level (*see diagram, preceding page*). In order for the signal to be considered valid, and not as noise, the signal must exceed, or cross, the upper or lower limits of this band by half the hysteresis-division setting.

level

For selecting the voltage or amplitude-percentage setting of the level on the waveform at which the timing is to be measured. And to select whether the measurement should be made on a "**Pos**"-itive (rising) edge, or a "**Neg**"-ative (falling) edge.

wid@lv — width at level Returns the width, positive or negative, of each pulse in the acquired waveform.

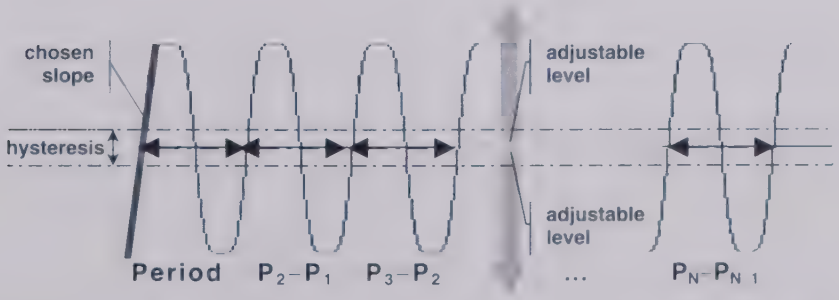
The menus and setup for this parameter are the same as for those shown on the previous pages.



w@lv: measures the width of all pulses in the waveform; level, slope and hysteresis are specified by the user.

Δp@lv — delta period at level Calculates the adjacent cycle deviation (cycle–to–cycle jitter) of each cycle in an acquired waveform.

The menus and setup for this parameter are the same those shown on the previous pages .

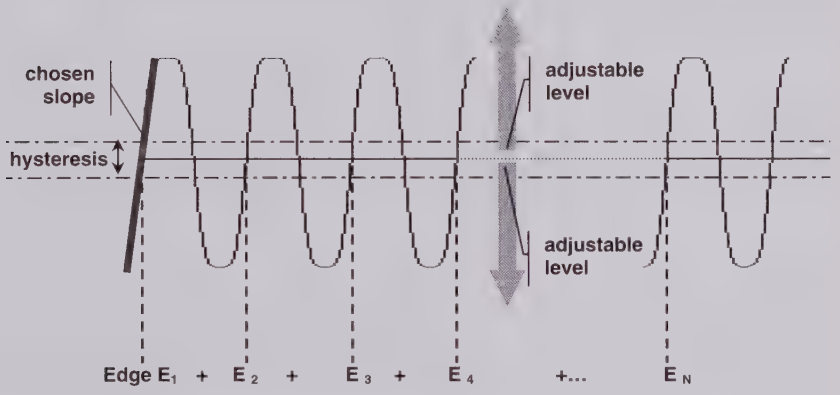


Δp@lv: measures the difference between consecutive cycles in the waveform; level, slope and hysteresis are specified by the user.

edge@lv — edge at level

Counts the number of edges, positive or negative, in the source trace.

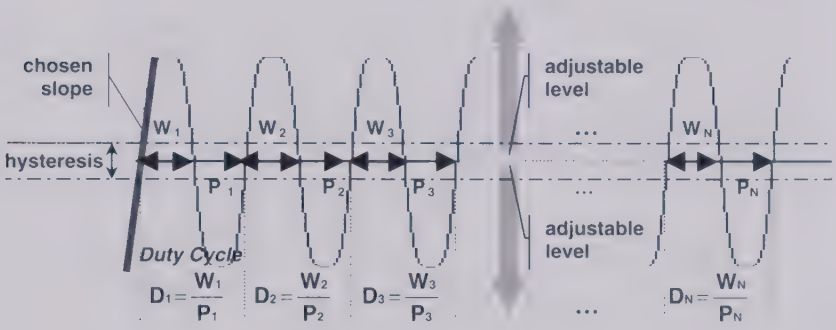
The menus and setup for this parameter are the same those shown on pages 5–3 and 5–4.



Δp@lv: counts the number of rising, or falling, edges in the waveform; level, slope and hysteresis are specified by the user.

duty@lv — duty cycle at level Calculates the duty cycle of each period in the source trace.

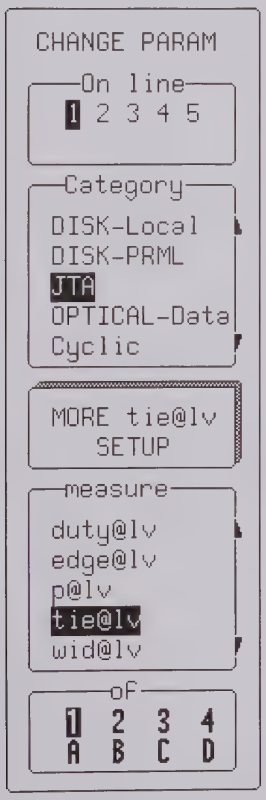
The menus and setup for this parameter are the same those shown on pages 5–3 and 5–4.



duty@lv: measures the duty cycle of each period in the waveform (pulse width over period); level, slope and hysteresis are specified by the user.

tie@lv — time interval error at level

Calculates the time interval error in the signal, compared with an "ideal" reference position defined by the user.



On line

To select, for modification, as many as five different parameters, each placed on a line: "**1**", "**2**", "**3**", "**4**" or "**5**".

Category

To specify the category of parameter. When "**JTA**" is selected, the "measure" menu (*below*) will feature the JTA Timing Parameters.

MORE tie@lv SETUP

Primary menu that calls up the secondary "SETUP tie@lv" menus (*next page*).

measure

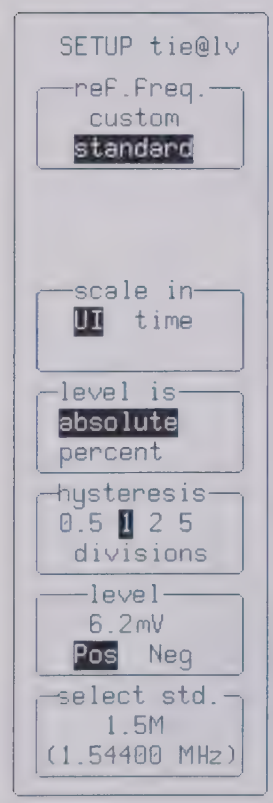
To choose the new parameter to be measured on the selected line.

of

For selecting the channel or trace on which the parameter will be measured (*four-channel menu shown*).

SETUP tie@lv

The menus shown here, particular to *tie@lv*, enable the parameter to be set up. Selected is the level on the pulse at which the measurement will be made, as well as the value in which the level is to be expressed: V or %. Also enabled is whether the measurement will be made at a positive or negative edge. The hysteresis is also defined.



ref. freq.

Enables the choice for the reference clock of either a "**custom**", user-defined frequency, or selection from a list of "**standard**", pre-defined frequencies. The frequency is adjusted using the "select..." menu (*see below*).

scale in

Expresses the parameter in either "**UI**" unit intervals or seconds ("**time**").

level is

Determines whether the levels should be set in "**absolute**" — in volts — or as a "**percent**"-age of signal amplitude.

hysteresis

Defines the hysteresis, in divisions. A voltage band is extended equidistantly above and below the selected level. In order for the signal to be considered valid, and not as noise, the signal must exceed, or cross, the upper or lower limits of this band by half the hysteresis-division setting.

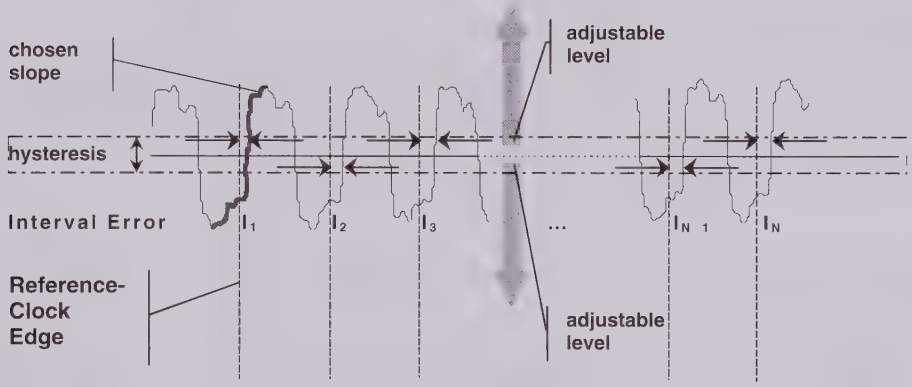
level

For selecting the voltage or amplitude-percentage setting of the level on the waveform at which the timing is to be measured. And to select whether the measurement should be made on a "**Pos**"-itive (rising) edge, or a "**Neg**"-ative (falling) edge.

select...

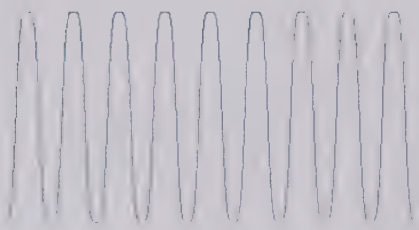
When "**custom**" has been chosen from the "ref. freq." menu, a particular user-defined frequency can be selected. The corresponding button for this menu highlights the mantissa (the exponent or the number of digits), while the associated knob changes the value highlighted.

When "**standard**" has been chosen, selection from a number of predefined frequencies can be made for the reference clock, using the menu button.



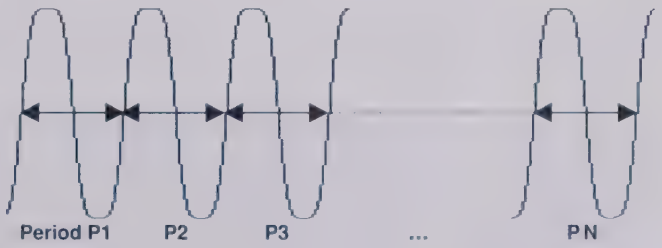
tie@lv: measures the time-interval error in each waveform pulse against a specified reference clock; level, slope and hysteresis are also specified by the user.

How Histograms are Made and Used

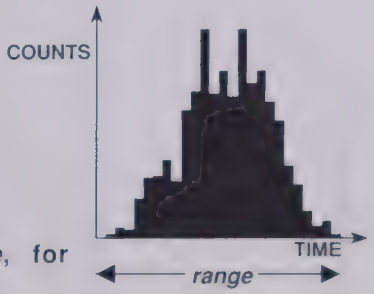


- Display the waveform to be analyzed.

- Apply a Timing Parameter — *period at level (p@lv)*, for example.



- Create a Histogram of the Parameter.



- Apply another (Histogram) Parameter — *range*, for example — to the Histogram itself.

Histograms graph the statistical distribution of a Timing Parameter's set of values. The histogram bar chart is divided into intervals, or bins. The height of each bar in the chart is proportional to the number of data points contained in each of its bins: the higher the bar, the more points there are in those bins and in the area of the waveform they represent.

A histogram can identify the type of statistical distribution in the waveform, helping to establish whether signal behavior is expected or not. Distribution tails or extreme values related to noise, or other infrequent, non-repetitive sources, may also be noted. Revealed, too, are multiple frequencies or amplitudes that help separate out jitter and noise.

Setting Up for Histograms

First, select a Timing Parameter. The example shown here (*Fig. 6.1*) shows a *period at level* (*p@lv*) parameter measurement for a sine waveform on Channel 2.

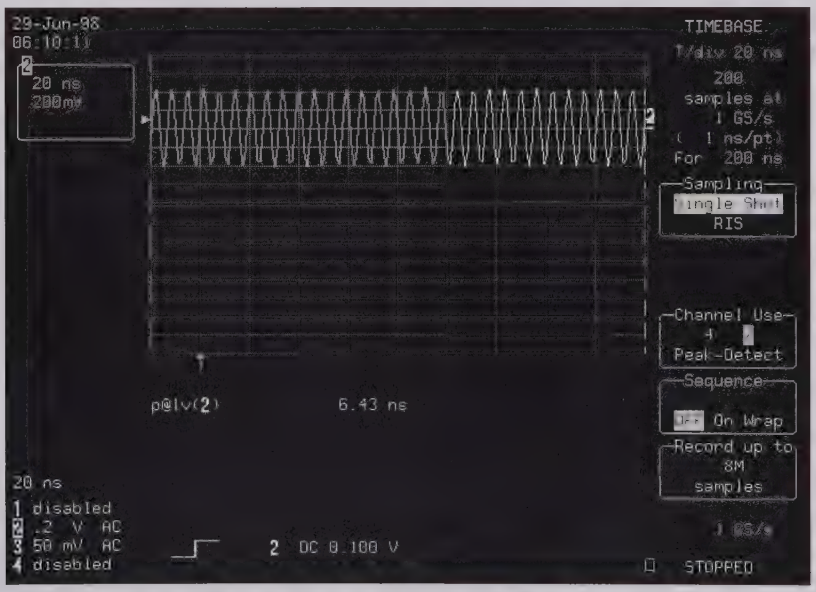


Figure 6.1. The waveform displayed, a Timing Parameter is chosen for histogramming.

The example waveform has 30 cycles, with thirty *p@lv* parameter values for each histogram and each sweep. A histogram based on *p@lv* can be now be created. But before this, the waveform trace must be *defined* as a histogram.

1. Press MATH SETUP

2. Then press the menu button corresponding to "REDEFINE A", for example, placing the histogram on Trace A.

3. Select "**Yes**" from the "use Math?" menu to enable math functions, including histogramming.

4. Choose "Histogram" from the "Math Type" menu.

Figure 6.2 shows the display when "**Histogram**" has been selected. Here, *p@lv* is the only Timing Parameter selected.

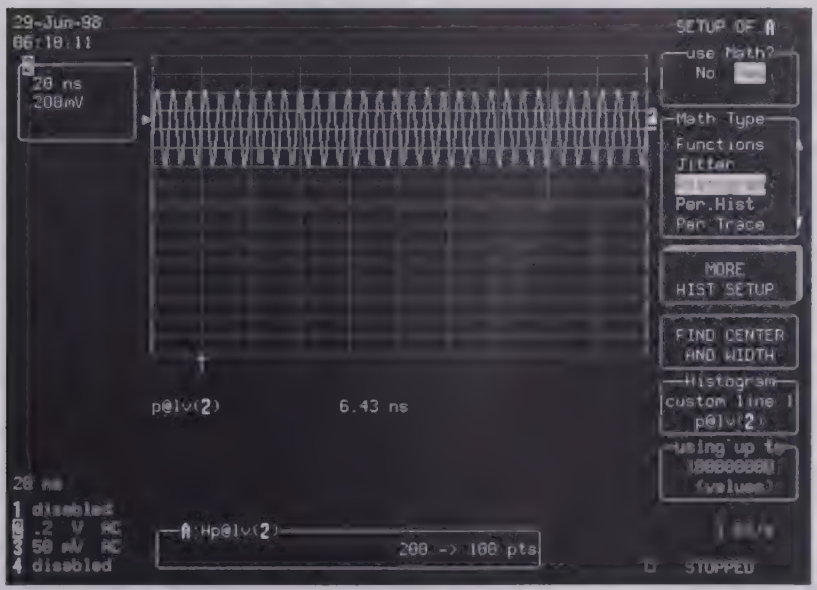


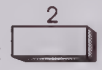
Figure 6.2. The waveform has been defined as a histogram; p@lv is on custom line 1. Note the information field beneath the grid indicating that Trace A is a histogram of p@lv for the waveform on CH 2.

5. For more Timing Parameters, press or turn to obtain the parameter in the "Histogram custom line" menu.

Each time a waveform-parameter value is calculated it is placed in a histogram bin. The maximum number of such values is selected from the "using up to" menu (*Fig 6.2*). From 20–2 billion parameter-value calculations can be histogram displayed.

Displaying a Histogram

To display the histogram bar chart:

6. Press the appropriate TRACE ON/OFF button, here: 

7. Select the "FIND CENTER AND WIDTH" menu to allow calculation of the optimal center and bin-width values, based on the most recently calculated parameter values. The number of parameter calculations is chosen with the "using up to" menu ("20 000 values" if greater than this number). *Figure 6.3* shows a typical result.

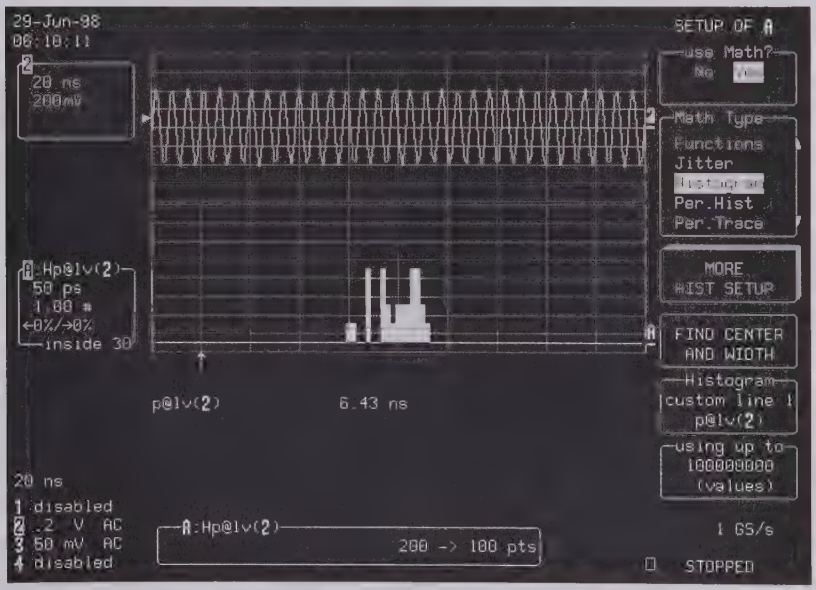
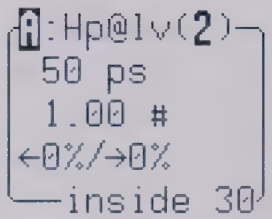


Figure 6.3. The histogram bar chart is displayed on Trace A.

Setting Histogram Range

Histograms are set up to capture parameter values falling within a specified range. As the oscilloscope captures the values in this range, the histogram's bin counts increase. Values that do not fall within the range are not used.

A histogram's range is represented by the horizontal width of the entire histogram baseline.



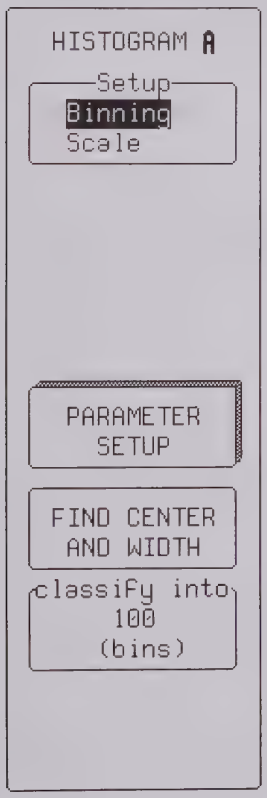
Statistical information from the histogram is reported in the Displayed Trace Field. The information includes:

- The current horizontal-per-division setting for the histogram — "50 ps" in the example. The unit of expression is in accordance with the type of parameter from which the histogram has been made.
- The vertical scale in number (#) of bin counts per division — here, "1.0".
- The number of parameter values that fall *inside* the range — "30", the number of cycles in the waveform.
- The percentage of parameter values that fall below, and above, the range — here, "←0%/→0%".

Histograms can be positioned and zoomed like any other waveform. If the trace on which the histogram is made is *not* a zoom, all bins having events will be displayed.

8. Press RESET to reset the trace and display *all* histogram events.
9. Select "MORE HIST SETUP" to specify additional histogram settings: the "HISTOGRAM..." menus described on the next page will appear.

Setting Binning and Scale



Setup

Allows adjustment of either the histogram binning or scale settings.

When "**Binning**" is selected, the "classify into" menu appears (*see below*). The number of bins can be set within a range of 20–2000 in a 1–2–5 sequence, by pressing the corresponding menu button or turning the associated knob. *For "**Scale**" options see next page.*

PARAMETER SETUP

To access the "CHANGE PARAM" menu group for selection of new, or modification of current, Timing Parameters. Or for selection of Histogram Parameters (*see page 6–8*).

FIND CENTER AND WIDTH

For calculating optimal center- and bin-width values for the histogram.

classify into

For choosing the number of bins into which the parameter events are to be classified, or distributed.

Setup

Allows adjustment of either the histogram binning or scale settings. When "**Scale**" is selected, the menus shown here appear.

vertical

For setting the vertical scale:

- "**Linear**" sets a linear vertical scale. The baseline of the histogram designates a bin value of "0". As the bin counts increase beyond those that can be displayed on screen, the scale is automatically increased in a 1–2–5 sequence.
- "**Log**" sets a logarithmic vertical scale. Because a value of "0" cannot be specified logarithmically, no baseline is provided.
- "**LinConstMax**" sets the vertical scaling to a linear value that uses close to the full vertical display capability of the instrument. The height of the histogram will remain nearly constant.

The oscilloscope automatically increases the vertical scale setting as required, ensuring that the highest histogram bar does not exceed the vertical screen display limit.

PARAMETER SETUP

To access the "CHANGE PARAM" menu group for selection of new, or modification of current, Timing Parameters. Or for selection of Histogram Parameters (*see next page*).

FIND CENTER AND WIDTH

For calculating optimal center- and bin-width values for the histogram (*see menus below*).

Center

To set the histogram center value.

Width

To set the histogram width value per division. The width per division multiplied by the number of horizontal display divisions (ten) determines the range of parameter values centered on the number in the "Center" menu, used to create the histogram.

Applying Histogram Parameters

The histogram made and its settings adjusted to provide desired information, additional parameter values — Histogram Parameters — can be applied to measure particular attributes of the histogram itself (*for the complete list of Histogram Parameters, see Appendix A*).

1. Select "PARAMETER SETUP" to access the "CHANGE PARAM" menus (*Fig. 6.4*).
2. Highlight "**Statistics**" in the Category menu, and choose one or more Histogram Parameters from the "measure" menu, to be placed using the "On line" menu.

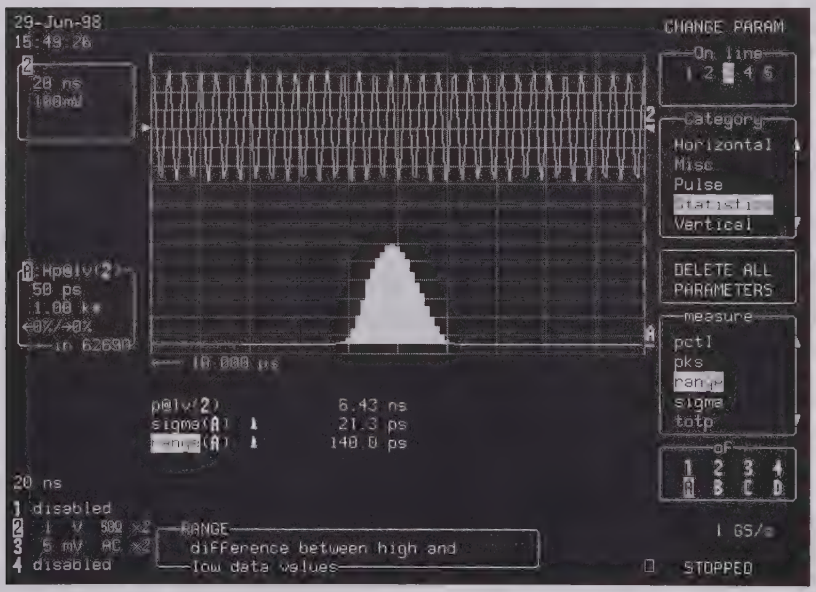


Figure 6.4. The CHANGE PARAM menus enable selection of Histogram Parameters such as sigma and range, and their placement on a line.

In this figure the Histogram Parameters *sigma* and *range* have been selected. *Sigma* determines the standard deviation of the histogram distribution, while range gives the horizontal difference between the high and low values.

The "**A**" beside the parameters listed under the grid indicates that the measurements are being made on the signal on Trace A — the histogram. Also indicated:

- a "**sigma (A)**" value of "23.2 ps"
- a "**range (A)** value of "140 ps"
- by the icon: that these parameters are indeed applied to a trace defined as a histogram.

However, if these parameters were inadvertently set for a trace with no histogram they would show '---'.

Zooms & Segments

The vertical and horizontal POSITION and ZOOM control knobs can be used to expand and position the histogram, and for zooming-in on a particular feature. The resulting vertical and horizontal scale settings are shown in the Displayed Trace Field for the trace.

Histograms can also be displayed for traces that are zooms of segmented waveforms. When a segment from a zoomed trace is selected, the histogram for that segment will appear. Only the portion of the segment displayed, and which is between the parameter cursors, will be used in making the histogram. The Displayed Trace Field will show the number of events captured for the segment.

Clearing Events

Press CLEAR SWEEPS at any time to clear histogram events. All events in the 20 000-parameter buffer are cleared at the same time.

However, the values in the "Center" and "Width" menus will *not* change, since they determine the range of the histogram and *cannot* be used to determine the parameter value range of a particular bin. If the histogram is repositioned using the horizontal POSITION knob the histogram's center will be moved from the center of the screen.

Using Cursors on Histograms

The measurement cursors are useful for determining the value and population of particular histogram bins.

1. Press

to access the "MEASURE" group and select "**Cursors**" from the top menu.
2. Choose the cursor required using the "mode", "type" and "show menus" (*see the oscilloscope Operator's Manual for more on cursors*).

Figure 6.5 shows the time cursor (downward-pointing arrow) positioned on a selected bin in Trace A, which corresponds to the cross-hair cursor on the waveform. The value of the bin and its population are also indicated, in the Displayed Trace Field.

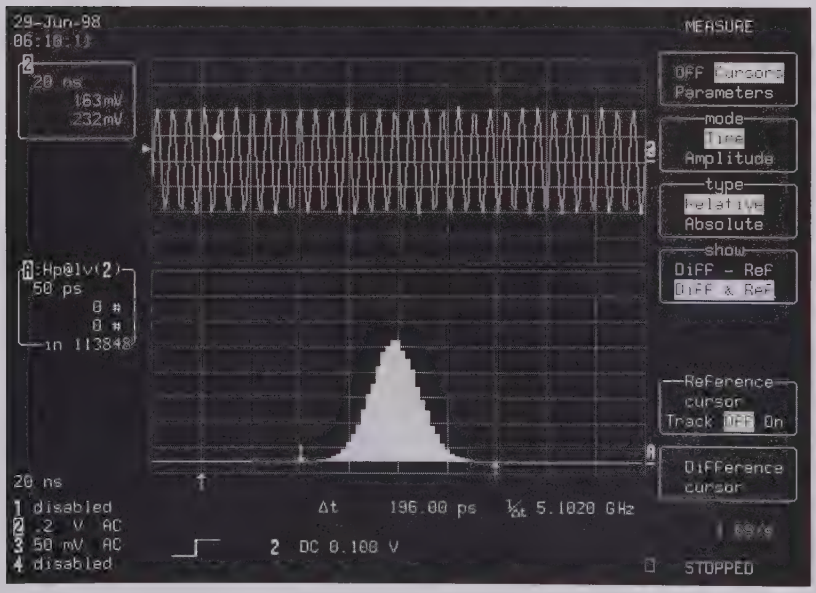
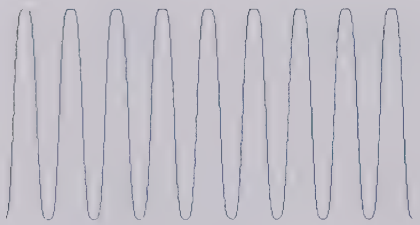


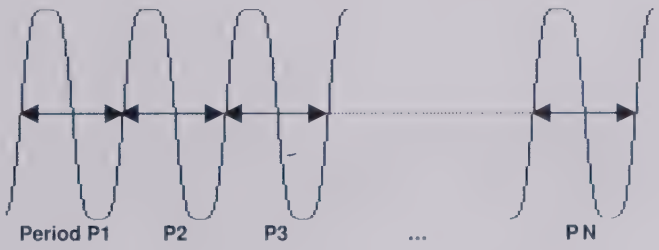
Figure 6.5. Cursors enable measurement of particular histogram bins.

How to Use the Trend Tool



➢ Display the waveform to be analyzed.

➢ Apply a Timing Parameter — *period at level (p@lv)*, for example.



➢ Plot the Trend of the Parameter.

Set Up and Configure for Trends

The Trend Statistical Tool visualizes the evolution of a Timing Parameter over time in the form of a line graph. The graph's vertical axis is the value of the parameter; its horizontal axis the order in which values were acquired (*see illustration previous page*

Before the Trend can be plotted, the Timing Parameter of which the Trend is to be made must be selected (*see Chapter 5*). To configure and then display Trends, follow these steps:

1. Press MATH SETUP
2. Then press the menu button corresponding to "REDEFINE A", for example. This will place the Trend on Trace A.
3. Select "**Yes**" from the "use Math?" menu to enable math functions, including trending (*see following pages for menus*).
4. Choose "Trend" from the "Math Type" menu.
5. Select the line to be used in the Trend.
6. Choose the number of values to be placed in the generated Trend
7. Decide whether all the parameters generated from the waveform or only the average of all parameter calculations for each waveform acquisition should be placed in the Trend.
8. For more Timing Parameters, press or turn to obtain the parameter in the "Histogram custom line" menu.
9. Press the appropriate TRACE ON/OFF button 2 to display the Trend.
10. Select the "FIND CENTER AND WIDTH" menu to position the Trend automatically.

use Math?

To choose a math function.

Math Type

For selecting "**Trend**".

MORE TREND SETUP

To access more trend setup options and the final trend-dedicated menu (*next page).*

FIND CENTER AND HEIGHT

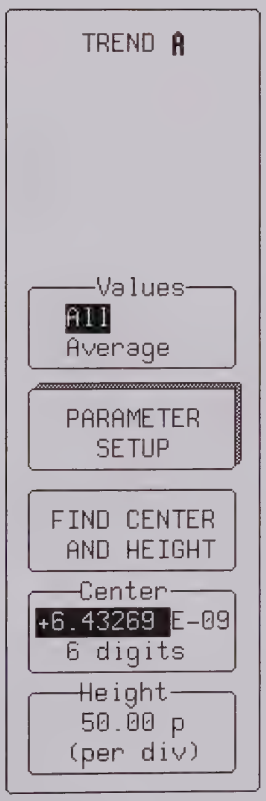
For positioning the trend automatically once it has been calculated. "FIND CENTER AND HEIGHT" places the trace appropriately, centering and scaling the trend without affecting the zoom and position settings.

Trend of

To select the parameter for trending, using the corresponding menu button or associated knob. Any of the configured parameters, displayed on the line beneath the grid, can be chosen.

using up to

For selecting — using button or knob — the number of values in the trend. A maximum of 20 000 values can be chosen for any one trend. When this maximum is exceeded, the parameter results scroll off the trend.



Values

To select "**All**" — for every parameter calculation on each waveform to be placed in the trend. Or "**Average**" — to trend only the average of all the given values calculated on a given acquisition, and to obtain one point in the trend per acquisition. Unless this is specifically required, "All" should be selected.

PARAMETER SETUP

To access the "CHANGE PARAM" menu group for selection of new, or modification of current, Timing Parameters.

FIND CENTER AND HEIGHT

For positioning the trend automatically once calculated. "FIND CENTER AND HEIGHT" places the trace appropriately, centering and scaling the trend without affecting the zoom and position settings.

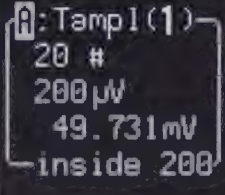
Center

To set the trend center value.

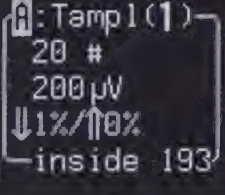
Height

To select the value of each vertical display division. The height per division multiplied by the number of vertical display divisions (eight) determines the range of parameter values centered on the number in the "Center" menu, used to create the trend.

Reading Trends: *A trend is like any other waveform: its horizontal axis is in units of eventswith earlier events in the leftmost part of the waveform and later events to the right. And its vertical axis is in the same units as the trended parameter. When the trend is displayed, trace labels like the ones below — for Trace A in these examples — appear in their customary place on-screen, identifying the trace, the math function performed and giving horizontal and vertical information...*



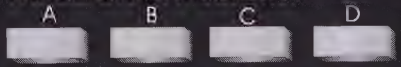
- # number of events per horizontal division
- Units per vertical division, in units of the parameter being measured
- Vertical value at point in trend at cursor location when using cursors
- Number of events in trend that are within unzoomed horizontal display range. ,



- Percentage of values lying beyond the unzoomed vertical range when *not* in cursor measurement mode.

Note:

- *The display of defined traces is controlled by the TRACE ON/OFF buttons.*



- *Expansion, or zooming, and positioning of traces is controlled by the horizontal and vertical ZOOM and POSITION knobs.*

- *When Multi-zoom is on, the ZOOM and POSITION knobs are coupled and control all displayed traces at once. This is particularly useful when multiple trends of related parameters are displayed.*

- *The*

button resets the multiplier for the trace expansion to '1' and the offset positioning to '0'. The button should be pressed for each reconfigured trace in order that traces can be cleanly and correctly positioned on-screen.

Histogram and Trend Calculation

With the oscilloscope configured for Histograms or Trends (*as described in the previous chapters*), the Timing Parameter values are calculated and the chosen function performed on each subsequent acquisition. The Histogram or Trend values themselves are calculated immediately following each acquisition.

The result is a waveform of data points that can be used the same way as any other waveform. Other parameters can be calculated on it. And it can be zoomed, serve as the *x* or *y* trace in an XY plot, or used in cursor measurements.

Acquisition Sequence

The sequence for acquiring Histogram or Trend data is:

1. Trigger
2. Waveform Acquisition
3. Parameter Calculation(s)
4. Histogram Update
5. Trigger re-arm.

If the timebase is set in non-segmented mode, a single acquisition occurs prior to parameter calculations.

However, in segment mode an acquisition for each segment occurs prior to parameter calculations. If the source of Histogram or Trend data is a memory, storing new data to memory effectively acts as a trigger and acquisition. Because updating the screen can take significant processing time, it occurs only once a second, minimizing trigger dead-time (under remote control the display can be turned off to maximize measurement speed).

Parameter Buffer

The oscilloscope maintains a circular parameter buffer of the last 20 000 measurements made, including values that fall outside the set histogram range. If the maximum number of events to be used in a histogram or trend is a number 'N' less than 20 000, the histogram will be continuously updated with the last 'N' events as new acquisitions occur. If the maximum number is

greater than 20 000, the histogram or trend will be updated until the number of events is equal to 'N'. Then, if the number of bins or the histogram or trend range is modified, the scope will use the parameter buffer values to redraw the histogram with either the last 'N' or 20 000 values acquired — whichever is the lesser. The parameter buffer thereby allows histograms or trends to be redisplayed using an acquired set of values and settings that produce a distribution shape with the most useful information.

In many cases the optimal range is not readily apparent. So the scope has a powerful range-finding function. If required it will examine the values in the parameter buffer to calculate an optimal range and redisplay the histogram or trend using it. The instrument will also give a running count of the number of parameter values that fall within, below and above the range. If any fall below or above the range, the range-finder can then recalculate to include these parameter values, as long as they are still within the buffer.

Parameter Events Capture

The number of events captured per waveform acquisition or display sweep depends on the type of parameter. Acquisitions are initiated by the occurrence of a trigger event. Sweeps are equivalent to the waveform captured and displayed on an input channel (1, 2, 3 or 4).

For non-segmented waveforms an acquisition is identical to a sweep. Whereas for segmented waveforms an acquisition occurs for each segment and a sweep is equivalent to acquisitions for all segments. Only the section of a waveform between the parameter cursors is used in the calculation of parameter values and corresponding histogram events.

The following table provides, for each parameter and for a waveform section between the parameter cursors, a summary of the number of Histogram or Trend events captured per acquisition or sweep.

Parameter	Number of Events Captured
JTA Timing Parameters: p@lv, wid@lv, Δp@lv, edge@lv, duty@lv, tie@lv	Unlimited number of events per acquisition.
data	All data values in the region analyzed.
duty, freq, period, width,	Up to 49 events per acquisition.
ampl, area, base, cmean, cmedian, crms, csdev, cycles, delay, dur, first, last, maximum, mean, median, minimum, nbph, nbpw, over+, over–, phase, pkpk, points, rms, sdev, Δdly, Δt@lv	One event per acquisition.
f@level, f80–20%, fall, r@level, r20–80%, rise	Up to 49 events per acquisition.

Zoom Traces and Segmented Waveforms

Histograms and Trends of zoom traces display all events for the displayed portion of a waveform between the parameter cursors. When dealing with segmented waveforms, and when a single segment is selected, the histogram or trend will be recalculated for all events in the displayed portion of this segment between the parameter cursors. But if "**All Segments**" is selected, the histogram or trend for all segments will be displayed.

Histogram Peaks

Because the shape of histogram distributions is particularly interesting, additional parameter measurements are available for analyzing these distributions. They are generally centered around one of several peak value bins. known — together with its associated bins — as a histogram peak.

Example

A histogram of the voltage value of a five-volt amplitude square wave is centered around two peak value bins: 0 V and 5 *V (Fig. A–1*). The adjacent bins signify variation due to noise. The graph of the centered bins shows both as peaks.

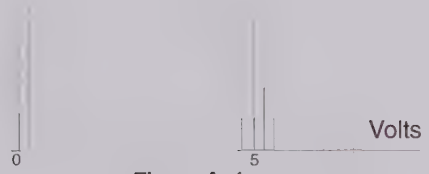


Figure A–1

Determining such peaks is very useful, as they indicate dominant values of a signal.

However, signal noise and the use of a high number of bins relative to the number of parameter values acquired, can give a jagged and spiky histogram, making meaningful peaks hard to distinguish. The scope analyzes histogram data to identify peaks from background noise and histogram definition artifacts such as small gaps, which are due to very narrow bins.

Binning and Measurement Accuracy

Histogram bins represent a sub-range of waveform parameter values, or events. The events represented by a bin may have a value anywhere within its sub-range. However, parameter measurements of the histogram itself, such as average, assume that all events in a bin have a single value. The scope uses the center value of each bin's sub-range in all its calculations. The greater the number of bins used to subdivide a histogram's range, the less the potential deviation between actual event values and those values assumed in histogram parameter calculations.

Nevertheless, using more bins may require performance of a greater number of waveform parameter measurements, in order to populate the bins sufficiently for the identification of a characteristic histogram distribution.

Figure A–2 shows a histogram display of 17 999 parameter measurements divided or classified into 2000 bins. The standard deviation of the histogram sigma is 6.750 ps.

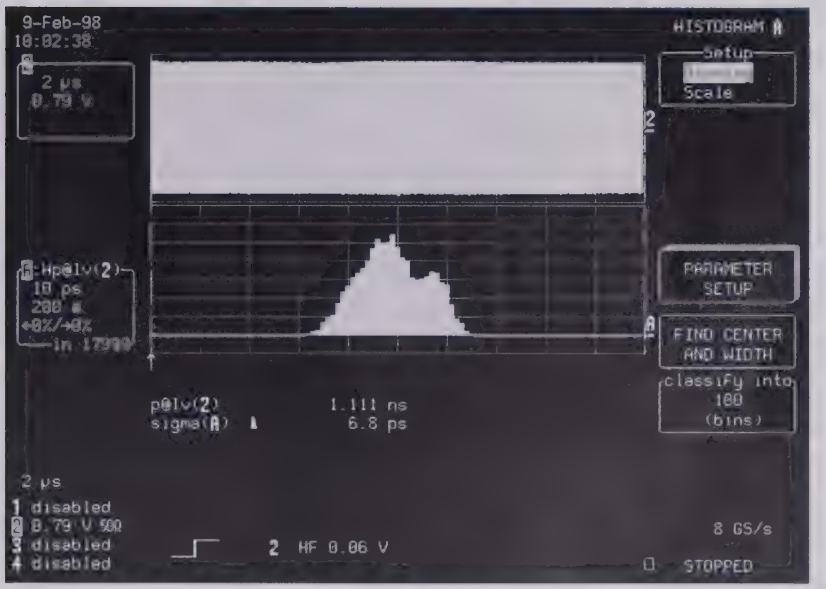


Figure A–2. Note the histogram's jagged appearance.

The oscilloscope's parameter buffer (*see page A–1*) is very effective for determining the optimal number of bins to be used. An optimal bin number is one where the change in parameter values is insignificant, and the histogram distribution does not have a jagged appearance. With this buffer, a histogram can be dynamically redisplayed as the number of bins is modified by the user. In addition, depending on the number of bins selected, the change in waveform parameter values can be seen.

In *Figure A–3* the histogram shown in the previous figure has been recalculated with 100 bins. Note how it has become far less jagged, while the real peaks are more apparent. Also, the change in sigma is minimal (6.750 ps vs 6.8 ps).

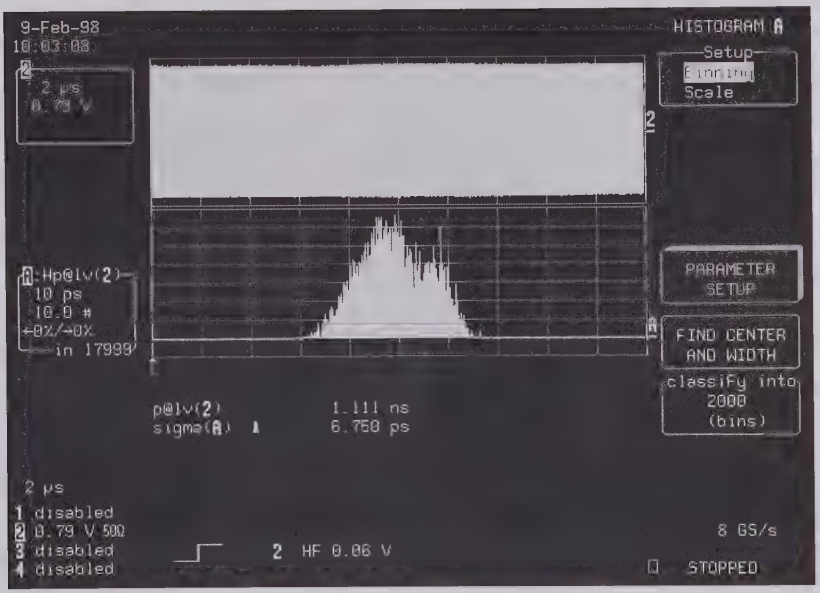

9-Feb-98
10:03:08
HISTOGRAM A
Setup
Binning
Scale
2 ps
0.79 V
A:Hp@lv(2)
10 ps
10.0 #
+0%/-0%
in 17939
PARAMETER SETUP
FIND CENTER AND WIDTH
classify into 2000 (bins)
p@lv(2) 1.111 ns
sigma(A) 6.750 ps
2 ps
1 disabled
2 0.79 V 50Ω
3 disabled
4 disabled
2 HF 0.06 V
8 GS/s
STOPPED

Figure A–2

avg Average

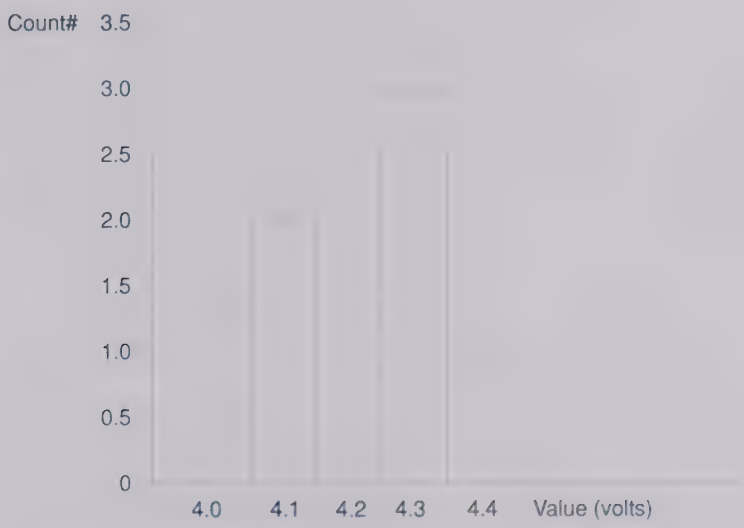
Definition Average or mean value of data in a histogram.

Description The average is calculated by the formula:

$$\text{avg} = \sum_{i=1}^{n} (\text{bin count})_i \, (\text{bin value})_i \; / \; \sum_{i=1}^{n} (\text{bin count})_i \, ,$$

where n is the number of bins in the histogram, bin count is the count or height of a bin, and bin value is the center value of the range of parameter values a bin can represent.

Example



The average value of this histogram is:

$$(4.1 * 2 + 4.3 * 3 + 4.4 * 1) / 6 = 4.25.$$

fwhm Full Width at Half Maximum

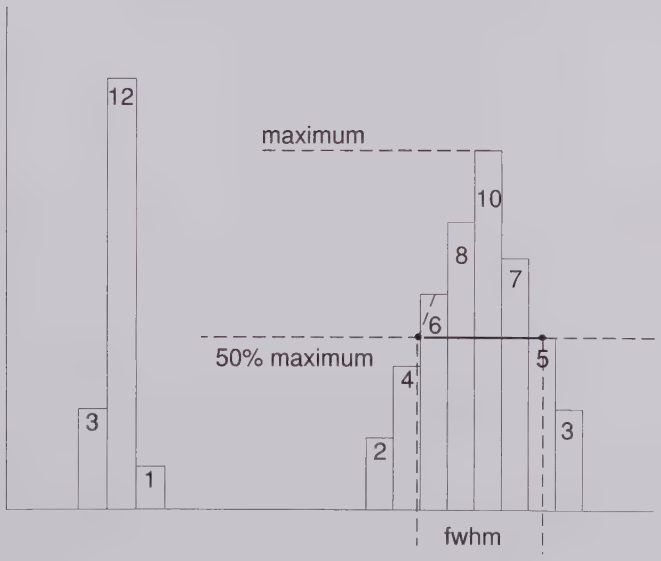
Definition

Determines the width of the largest area peak, measured between bins on either side of the highest bin in the peak that have a population of half the highest's population. If several peaks have an area equal to the maximum population, the leftmost peak is used in the computation.

Description

First, the highest population peak is identified and the height of its highest bin (population) determined (*for a discussion on how peaks are determined see the **pks** parameter description*). Next, the populations of bins to the right and left are found, until a bin on each side is found to have a population of less than 50% of that of the highest bin's. A line is calculated on each side, from the center point of the first bin below the 50% population to that of the adjacent bin, towards the highest bin. The intersection points of these lines with the 50% height value is then determined. The length of a line connecting the intersection points is the value for **fwhm**.

Example



fwxx Full Width at xx% Maximum

Definition

Determines the width of the largest area peak, measured between bins on either side of the highest bin in the peak that have a population of xx% of the highest's population. If several peaks have an area equal to the maximum population, the leftmost peak is used in the computation.

Description

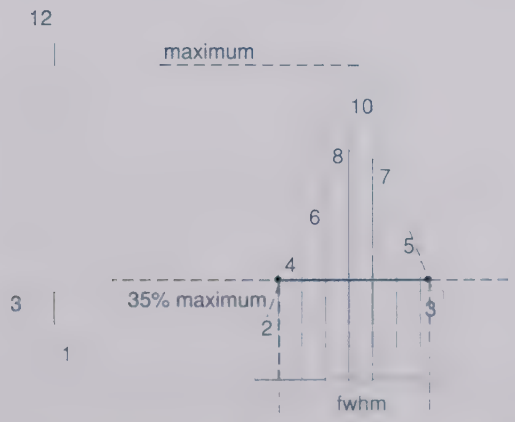
First, the highest population peak is identified and the height of its highest bin (population) determined (*see the **pks** description*). Next, the bin populations to the right and left are found until a bin on each side is found to have a population of less than xx% of that of the highest bin. A line is calculated on each side, from the center point of the first bin below the 50% population to that of the adjacent bin, towards the highest bin. The intersection points of these lines with the xx% height value is then determined. The length of a line connecting the intersection points is the value for **fwxx**.

Parameter Settings

Selection of the **fwxx** parameter in the "CHANGE PARAM" menu group causes the "MORE fwxx SETUP" menu to appear. Pressing the corresponding menu button displays a threshold setting menu that enables the user to set the 'xx' value to between 0–100% of the peak.

Example

fwxx with threshold set to 35%:



hampl Histogram Amplitude

Definition

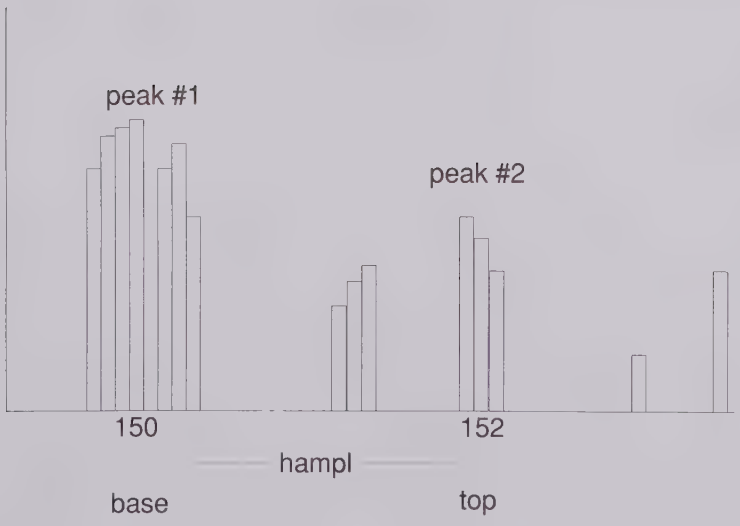
The difference in value of the two most populated peaks in a histogram. This parameter is useful for waveforms with two primary parameter values, such as TTL voltages, where **hampl** would indicate the difference between the binary '1' and '0' voltage values.

Description

The values at the center (line dividing the population of peak in half) of the two highest peaks are determined (*see **pks** parameter description*). The value of the leftmost of the two peaks is the histogram base (*see* **hbase**). While that of the rightmost is the histogram top (*see* **htop**). The parameter is then calculated as:

hampl = htop – hbase

Example



In this histogram, **hampl** is 152 mV – 150 mV = 2 mV.

Hbase — Histogram Base

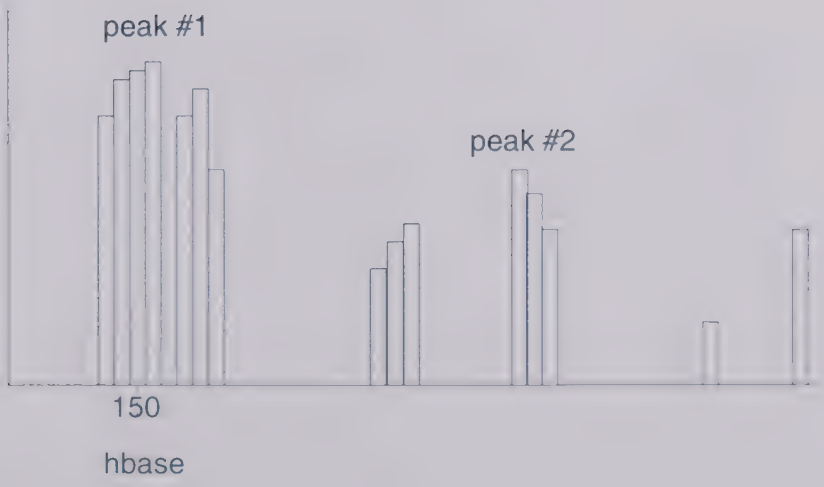
Definition

The value of the leftmost of the two most populated peaks in a histogram. This parameter is primarily useful for waveforms with two primary parameter values such as TTL voltages where **hbase** would indicate the binary '0' voltage value.

Description

The two highest histogram peaks are determined. If several peaks are of equal height the leftmost peak among these is used (*see* ***pks***). Then the leftmost of the two identified peaks is selected. This peak's center value (line that divides population of peak in half) is the **hbase**.

Example



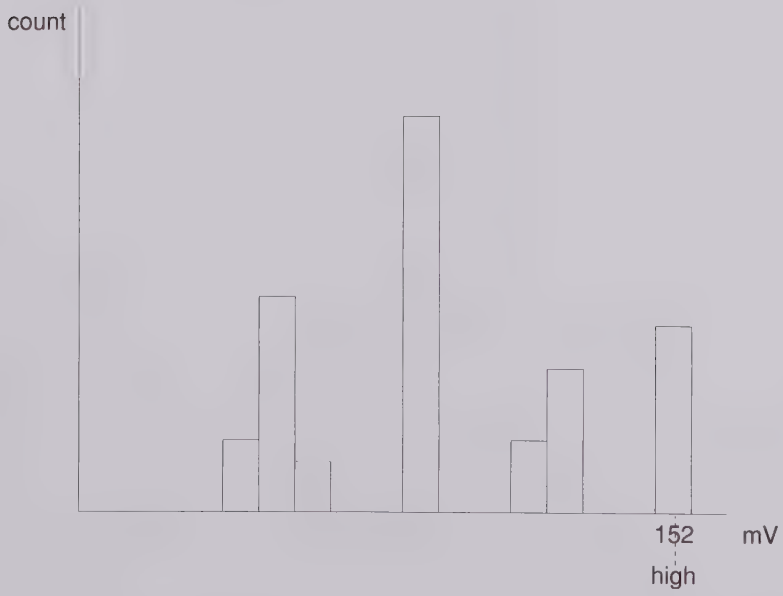
high

High

Definition The value of the rightmost populated bin in a histogram.

Description The rightmost of all populated histogram bins is determined: **high** is its center value, the highest parameter value shown in the histogram.

Example



In this histogram **high** is 152 mV.

hmedian — Histogram Median

Definition

The value of the 'x' axis of a histogram, dividing the histogram population into two equal halves.

Description

The total population of the histogram is determined. Scanning from left to right, the population of each bin is summed until a bin that causes the sum to equal or exceed half the population value is encountered. The proportion of the population of the bin needed for a sum of half the total population is then determined. Using this proportion, the horizontal value of the bin at the same proportion of its range is found, and returned as **hmedian**.

Example

The total population of a histogram is 100 and the histogram range is divided into 20 bins. The population sum, from left to right, is 48 at the eighth bin. The population of the ninth bin is 8 and its sub-range is from 6.1–6.5 V. The ratio of counts needed for half- to total-bin population is:

2 counts needed / 8 counts = .25

The value for **hmedian** is:

6.1 volts + .25 * (6.5 - 6.1) volts = 6.2 volts

hrms Histogram Root Mean Square

Definition The rms value of the values in a histogram.

Description The center value of each populated bin is squared and multiplied by the population (height) of the bin. All results are summed and the total is divided by the population of all the bins. The square root of the result is returned as **hrms**.

Example Using the histogram shown here, the value for **hrms** is:

$$\text{hrms} = \sqrt{(3.5^2 * 2 + 2.5^2 * 4)/6} = 2.87$$

htop Histogram Top

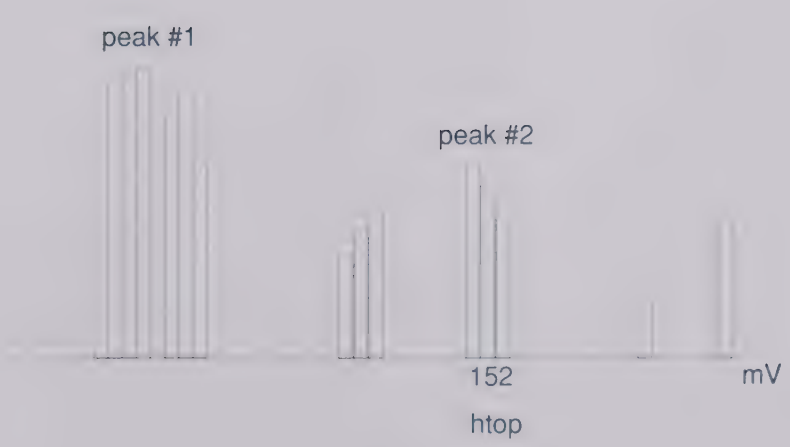
Definition

The value of the rightmost of the two most populated peaks in a histogram. This parameter is useful for waveforms with two primary parameter values, such as TTL voltages, where **htop** would indicate the binary '1' voltage value.

Description

The two highest histogram peaks are determined. The rightmost of the two identified peaks is then selected. The center of that peak is **htop** (center is the horizontal point where the population to the left is equal to the area to the right).

Example



low Low

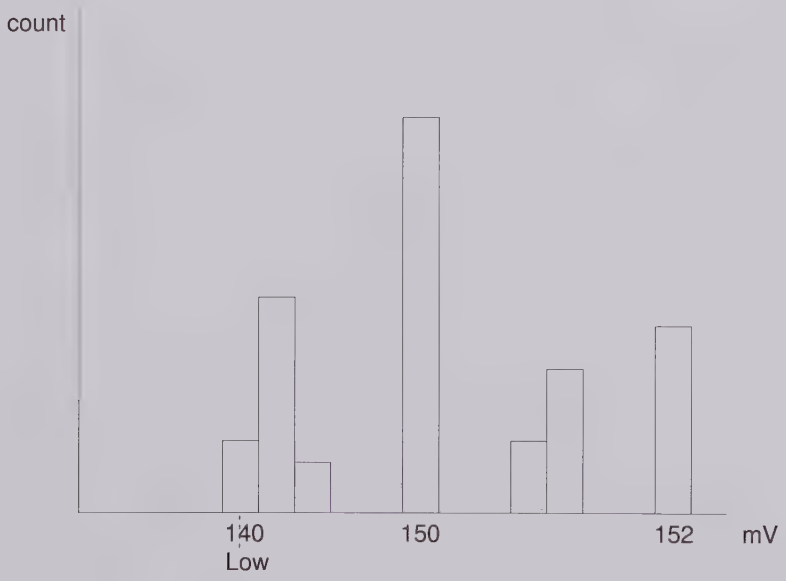
Definition

The value of the leftmost populated bin in a histogram population. It indicates the lowest parameter value in a histogram's population.

Description

The leftmost of all populated histogram bins is determined. The center value of that bin is **low**.

Example



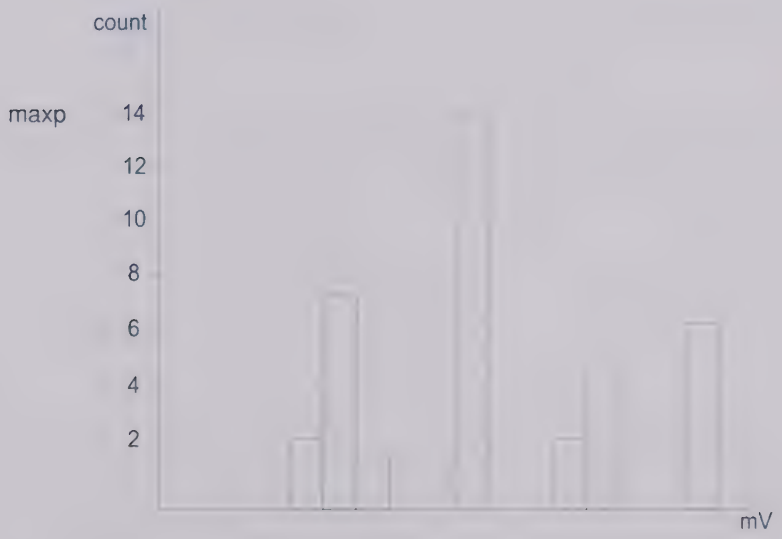
In this histogram **low** is 140 mV.

maxp Maximum Population

Definition The count (vertical value) of the highest population bin in a histogram.

Description Each bin between the parameter cursors is examined for its count. The highest count is returned as **maxp**.

Example



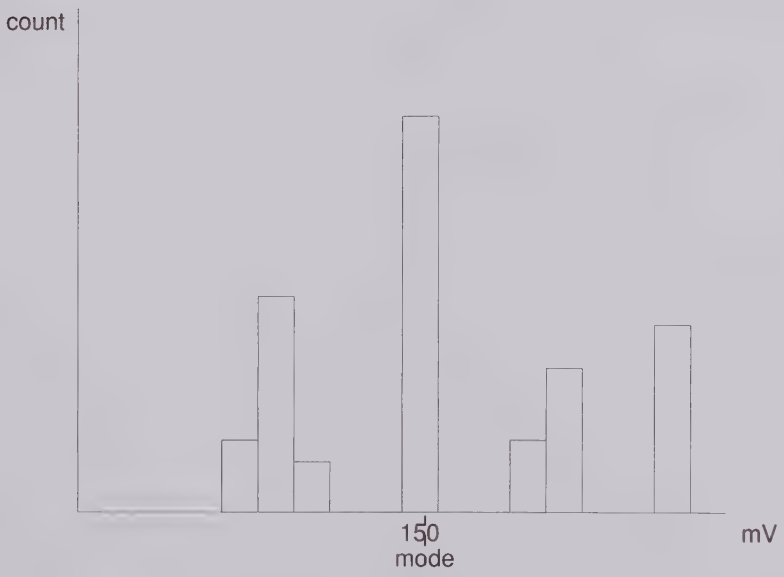
In this example, **maxp** is 14.

mode Mode

Definition The value of the highest population bin in a histogram.

Description Each bin between the parameter cursors is examined for its population count. The leftmost bin with the highest count found is selected. Its center value is returned as **mode**.

Example



In this example **mode** is 150 mV.

pctl — Percentile

Definition

Computes the horizontal data value that separates the data in a histogram, so that the population on the left is a specified percentage 'xx' of the total population. When the threshold is set to 50%, **pctl** is the same as **hmedian**.

Description

The total population of the histogram is determined. Scanning from left to right, the population of each bin is summed until a bin that causes the sum to equal or exceed 'xx'% of the population value is encountered. A ratio of the number of counts needed for 'xx'% population/total bin population is then determined for the bin. The horizontal value of the bin at that ratio point of its range is found, and returned as **pctl**.

Example

The total population of a histogram is 100. The histogram range is divided into 20 bins and 'xx' is set to 25%. The population sum at the sixth bin from the left is 22. The population of the seventh is 9 and its sub-range is 6.1–6.4 V. The ratio of counts needed for 25% population to total bin population is:

3 counts needed / 9 counts = 1/3.

The value for **pctl** is:

6.1 volts + .33 * (6.4 – 6.1) volts = 6.2 volts.

Parameter Settings

Selection of the **pctl** parameter in the "**CHANGE PARAM**" menu group causes the "**MORE pctl SETUP**" menu to appear. Pressing the correponding menu button displays a threshold setting menu. And with the associated knob the user can set the percentage value to between 1% and 100% of the total population.

pks Peaks

Definition

The number of peaks in a histogram.

Description

The scope analyzes histogram data to identify peaks from background noise and histogram binning artifacts such as small gaps.

Peak identification is a three-step process:

1) The mean height of the histogram is calculated for all populated bins. A threshold (T1) is calculated from this mean where:

   T1= mean + 2 sqrt(mean).

2) A second threshold is determined based on all populated bins under T1 in height, where:

   T2 = mean + 2 * sigma,

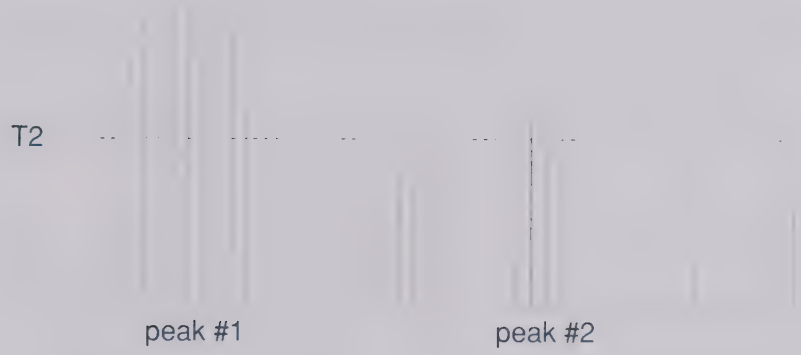
   and where sigma is the standard deviation of all populated bins under T1.

3) Once T2 is defined, the histogram distribution is scanned from left to right. Any bin that crosses above T2 signifies the existence of a peak. Scanning continues to the right until one bin or more crosses below T2. However, if the bin(s) cross below T2 for less than a hundreth of the histogram range, they are ignored, and scanning continues in search of a peak(s) that crosses under T2 for more than a hundreth of the histogram range. Scanning goes on over the remainder of the range to identify additional peaks. Additional peaks within a fiftieth of the range of the populated part of a range from a previous peak are ignored.

Note: If the number of bins is set too high a histogram may have many small gaps. This increases sigma and thereby T2, and in extreme cases can prevent determination of a peak, even if one appears to be present to the eye.

Example

The example below shows that two peaks have been identified. The peak with the highest population is peak #1.



range

Range

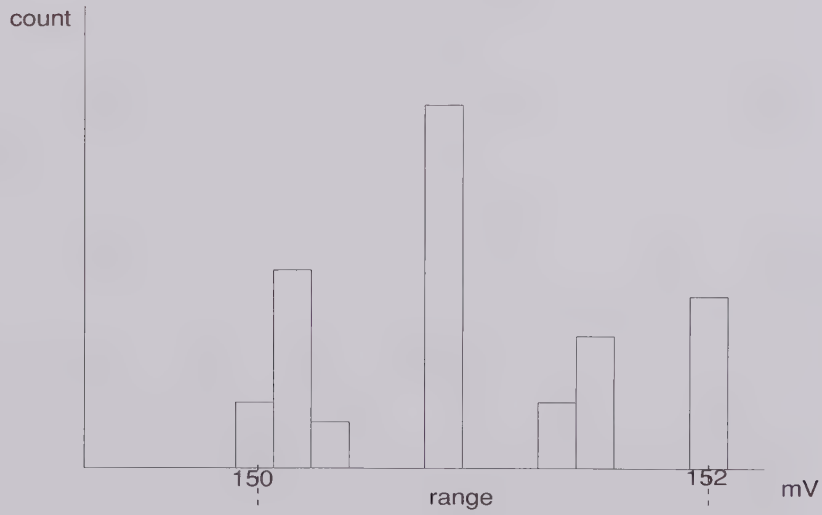
Definition

Computes the difference between the value of the rightmost and that of the leftmost populated bin.

Description

The rightmost and leftmost populated bins are identified. The difference in value between the two is returned as the **range**.

Example



In this example **range** is 2 mV.

sigma

Sigma

Definition The standard deviation of the data in a histogram.

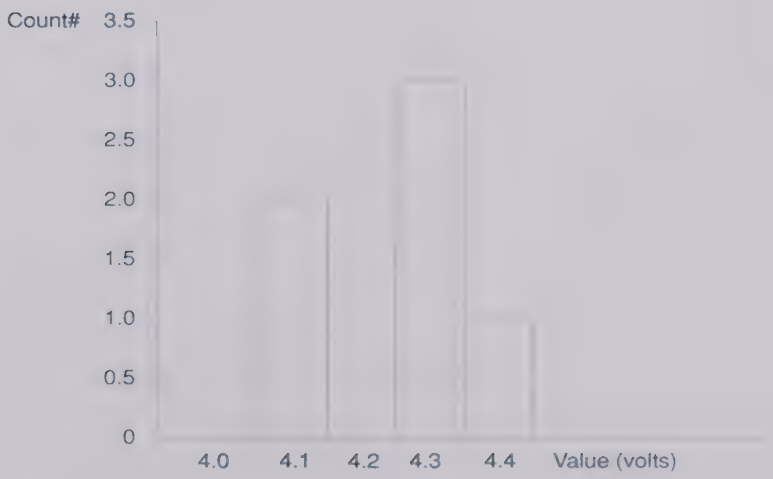
Description **sigma** is calculated by the formulas:

$$\text{mean} = \sum_{i=1}^{n} [\text{bin count}_i * \text{bin value}_i] / \left(\sum_{i=1}^{n} \text{bin count}_i \right);$$

$$\text{sigma} = \sqrt{\sum_{i=1}^{n} [\text{bin count}_i * (\text{bin value}_i - \text{mean})^2] / \left(\sum_{i=1}^{n} [\text{bin count}_i] - 1 \right)},$$

where n is the number of bins in the histogram, bin count is the count or height of a bin and bin value is the center value of the range of parameter values a bin can represent.

Example For the histogram:



$$\text{mean} = (2 * 4.1 + 3 * 4.3 + 1 * 4.4) / 6 = 4.25$$

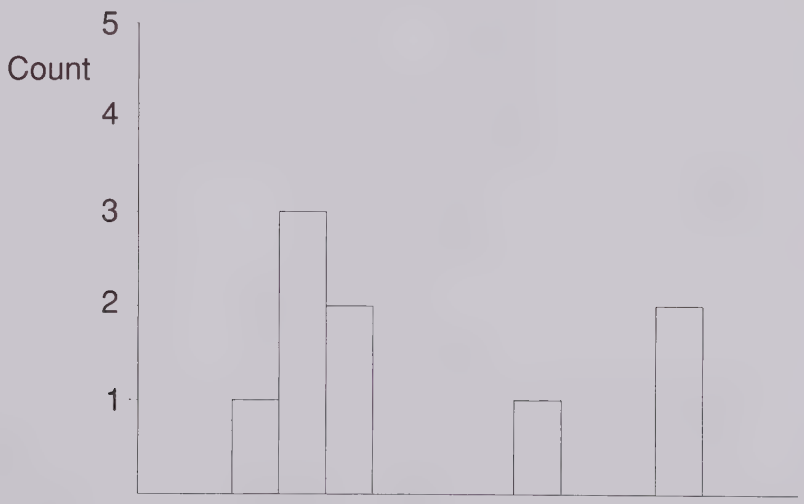
$$\text{sigma} = \sqrt{(2 * (4.1 - 4.25)^2 + 3 * (4.3 - 4.25)^2 + 1 * (4.4 - 4.25)^2) \quad (6 - 1)} = .1225$$

totp Total Population

Definition Calculates the total population of a histogram between the parameter cursors.

Description The count for all populated bins between the parameter cursors is summed.

Example



The total population of this histogram is 9.

xapk X Coordinate of xx'th Peak

Definition

Returns the value of the xx'th largest area peak in a histogram.

Description

First the peaks in a histogram are determined and ranked in order of total area (for a discussion on how peaks are identified see the description for the **pks** parameter). The center of the n'th ranked peak (the point where the area to the left is equal to the area to the right), where n is selected by the user, is then returned as **xapk**.

C Appendix C: JTA Remote Control Commands

CURSOR

PARAMETER_CUSTOM, PACU

Command/Query

DESCRIPTION

The PARAMETER_CUSTOM command controls the JTA timing parameters. Statistical parameters (common to JTA and WP03 options) and other standard parameters are described in the instrument's Remote Control Manual.

<param>	definition	<qualifier> list
JTA Timing Parameters		
DPLEV	delta period at level	<source>,<edge>,<level>,<hysteresis>
DULEV	duty cycle at level	<source>,<edge>,<level>,<hysteresis>
EDLEV	delta delay	<source>,<edge>,<level>,<hysteresis>
PLEV	delta time at level	<source>,<edge>,<level>,<hysteresis>
TIELEV	fall at level	<source>,<edge>,<level>,<hysteresis>,<scale>,<ref type>,<freq>
WIDLEV	phase difference	<source>,<edge>,<level>,<hysteresis>

Where:

<source> : = {C1, C2, C3[d],C4[d],TA, TB, TC, TD}
<edge> : = {POS, NEG }
<level> : = 1 to 99 if level is specified in percent (PCT). If PCT is not specified, the level is in the units of the <source> waveform.
<hysteresis> : = {0.5, 1, 2, 5} divisions
<scale> := {UI, s}
<ref_type> := {STD, CUST}
"CUST" <freq> := 10 to 1e9 Hz
"STD" <freq> := {1.5M,2M,8M,34M,44M,52M,139M,155M}

COMMAND SYNTAX

PArameter CUstom <line>, parameter>, <qualifier> [, <qualifier>....]
<line> : = 1 to 5
<parameter> : = {a parameter from the table below }
<qualifier> : = Measurement qualifier(s) specific to each.

Note: CUST1, CUST2, CUST3, CUST4, CUST5 refers to the custom line numbers of the selected custom parameters:

QUERY SYNTAX

PArameter_CUstom? <line>

RESPONSE FORMAT

PArameter_CUstom <line>, <parameter>, <qualifier> [,<qualifier>,...]

AVAILABILITY

<source> : = {C3, C4} available only on four-channel oscilloscopes.

EXAMPLES

DPLEV

Command Examples

Example 1: PACU 3,DPLEV,C2,POS,-280E–3,C2,1 DIV

Example 2: PACU 3,DPLEV,C2,NEG,23 PCT,1 DIV

Query/Response Examples

PACU? 3 returns:
Example 1: PACU 3,DPLEV,C2,POS,-280E–3 V,C2,1 DIV
Example 2: PACU 3,DPLEV,C2,NEG,23 PCT,1 DIV
PAVA? CUST3 returns:
C2:PAVA CUST1,1E-9 S,OK

TIELEV

Command Example

PACU 2,TIELEV,TB,POS,0E-3,1 DIV,UI,CUST,0.01E+3 HZ

Query/Response Examples

PACU? 2 returns:

PACU 2,TIELEV,TB,POS,0E-3 V,1 DIV,UI,CUST,0.01E+3 HZ

RELATED COMMANDS

PARAMETER_DELETE, PARAMETER_VALUE?, PARAMETER_STATISTICS, PARAMETER_CLR, PASS_FAIL_xxx,

FUNCTION — DEFINE, DEF

Command/Query

DESCRIPTION

The DEFINE command controls the JTA functions. This command is also used to control all functions in the standard oscilloscopes as well as the statistical functions common to JTA and WP03 options (see the instrument's Remote Control Manual).

COMMAND SYNTAX

<function>:DEFine EQN,"<equation>" [,<attribute_name>,<value>,...]

Note 1: Function attributes are grouped in pairs. The first in the pair, <attribute_name>, names the variable to be modified, while the second one <value>, gives the new value to be assigned. Pairs can be given in any order.

QUERY SYNTAX

<function>:DEFine?

RESPONSE FORMAT

<function>:DEFine EQN,"<equation>" [,<attribute_name>,<value>,...]

AVAILABILITY

<sourceN>:C3 and C4 — available only on 4-channel oscilloscopes.

RELATED COMMANDS

FIND_CTR_RANGE, FUNCTION_RESET, INR?

JITTER (Cycle-to-Cycle–)

<function>:DEF EQN, "JITTERCC (<source>)", SLOPE, <slope>, LEVEL, <level> , HYST, <hyst>

Where:

<source>:=	{C1, C2, C3, C4, TA, TB, TC, TD}
<function>: =	{TA, TB, TC, TD}
<slope> : =	{POS, NEG}
<level> : =	1 to 99 if level is specified in percent (PCT), or level in the units of the <source> waveform
<hyst> :=	{0.5, 1, 2, 5}

***Note:** Scaling of the JitterTrack Function "FIND JITTER RANGE" can be executed via the FIND_CTR_RANGE (FCR) command.*
*Example: **TA:FCR** scales JitterTrack on trace A.*

Command Examples

Absolute level:
TA:DEF EQN,"JITTERCC(C2)",SLOPE,POS,LEVEL,213.9E-3,HYST,0.5

Relative level:
TA:DEF EQN,"JITTERCC(C2)",SLOPE,POS,LEVEL,42 PCT,HYST,0.5

Query/Response Examples TA:DEF? returns:

Absolute level:
TA:DEF EQN,"JITTERCC(C2)",SLOPE,POS,LEVEL,213.9E-3 **V**,HYST,0.5

Relative level:
TA:DEF EQN,"JITTERCC(C2)",SLOPE,POS,LEVEL,42 PCT,HYST,0.5

JITTER (Duty Cycle–)

<function>:DEF EQN, "JITTERDUTY (<source>)", SLOPE, <slope>, LEVEL, <level> , HYST, <hyst>

Where:

<source>:=	{C1, C2, C3, C4, TA, TB, TC, TD}
<function>: =	{TA, TB, TC, TD}
<slope> : =	{POS, NEG}
<level> : =	1 to 99 if level is specified in percent (PCT), or level in the units of the <source> waveform
<hyst> :=	{0.5, 1, 2, 5}}

***Note:** Scaling of the JitterTrack Function "FIND JITTER RANGE" can be executed via the FIND_CTR_RANGE (FCR) command.*
***Example: TA:FCR** scales JitterTrack on trace A.*

Command Examples

Absolute level:
TA:DEF EQN,"JITTERDUTY(C2)",SLOPE,POS,LEVEL,213.9E-3,HYST,0.5

Relative level:
TA:DEF EQN,"JITTERDUTY (C2)",SLOPE,POS,LEVEL,42 PCT,HYST,0.5

Query/Response Examples TA:DEF? returns:

Absolute level:
TA:DEF EQN,"JITTERDUTY (C2)",SLOPE,POS,LEVEL,213.9E-3 V,HYST,0.5

Relative level:
TA:DEF EQN,"JITTERDUTY (C2)",SLOPE,POS,LEVEL,42 PCT,HYST,0.5

JITTER (Interval Error–)

<function>:DEF EQN, "JITTERIE(<source>)", SLOPE, <slope>, LEVEL, <level> , HYST, <hyst>, VERT_UNIT, <vunit>, **FREQ_STD, <std_freq>** (or **FREQ, <cust_freq>**)

Where:

<source>:=	{C1, C2, C3☝,C4☝,TA, TB, TC, TD}
<function>: =	{TA, TB, TC, TD}
<slope> : =	{POS, NEG}
<level> : =	1 to 99 if level is specified in percent (PCT), or level in the units of the <source> waveform
<hyst> :=	{0.5, 1, 2, 5}
<vunit> :=	{UI, S}
<std_freq> :=	{1.5M,2M,8M,34M,44M,52M,139M,155M}
<cust_freq> :=	10 to 1e9 Hz}

***Note:** Scaling of the JitterTrack Function "FIND JITTER RANGE" can be executed via the FIND_CTR_RANGE (FCR) command.*
*Example: **TA:FCR** scales JitterTrack on trace A.*

Command Examples

Absolute level, unit in UI, standard frequency:
TA:DEF EQN,"JITTERIE(C2)",SLOPE, POS, LEVEL, 5E-3,HYST,0.5,VERT_UNIT,UI,FREQ_STD,52M

Relative level, unit in time, custom frequency:
TA:DEF EQN,"JITTERIE(C2)",SLOPE,POS,LEVEL,42 **PCT**,HYST,0.5,VERT_UNIT,**S**,**FREQ,155.52E+6 HZ**

Query/Response Examples TA:DEF? returns:

Absolute level, unit in UI, standard frequency:
TA:DEF EQN,"JITTERIE(C2)",SLOPE, POS, LEVEL, 5E-3 **V**,HYST,0.5,VERT_UNIT,UI,FREQ_STD,52M

Relative level, unit in time, custom frequency:
TA:DEF EQN,"JITTERIE(C2)",SLOPE,POS,LEVEL,42 **PCT**,HYST,0.5,VERT_UNIT,**S**,**FREQ,155.52E+6 HZ**

JITTER (Period–)

<function>:DEF EQN, "JITTERP (<source>)", SLOPE, <slope>, LEVEL, <level> , HYST, <hyst>

Where:

<source>:=	{C1, C2, C3[ed],C4[ed],TA, TB, TC, TD}
<function>: =	{TA, TB, TC, TD}
<slope> : =	{POS, NEG}
<level> : =	1 to 99 if level is specified in percent (PCT), or level in the units of the <source> waveform
<hyst> :=	{0.5, 1, 2, 5}}

***Note:** Scaling of the JitterTrack Function "FIND JITTER RANGE" can be executed via the FIND_CTR_RANGE (FCR) command.*
***Example: TA:FCR** scales JitterTrack on trace A.*

Command Examples

Absolute level:
TA:DEF EQN,"JITTERP(C2)",SLOPE,POS,LEVEL,213.9E-3,HYST,0.5

Relative level:
TA:DEF EQN,"JITTERP (C2)",SLOPE,POS,LEVEL,42 PCT,HYST,0.5

Query/Response Examples TA:DEF? returns:

Absolute level:
TA:DEF EQN,"JITTERP (C2)",SLOPE,POS,LEVEL,213.9E-3 **V**,HYST,0.5

Relative level:
TA:DEF EQN,"JITTERP (C2)",SLOPE,POS,LEVEL,42 PCT,HYST,0.5

JITTER (Width–)

<function>:DEF EQN, "JITTERW (<source>)", SLOPE, <slope>, LEVEL, <level> , HYST, <hyst>

Where:

<source>:=	{C1, C2, C3☝,C4☝,TA, TB, TC, TD}
<function>: =	{TA, TB, TC, TD}
<slope> : =	{POS, NEG}
<level> : =	1 to 99 if level is specified in percent (PCT), or level in the units of the <source> waveform
<hyst> :=	{0.5, 1, 2, 5}}

***Note:** Scaling of the JitterTrack Function "FIND JITTER RANGE" can be executed via the FIND_CTR_RANGE (FCR) command.*
*Example: **TA:FCR** scales JitterTrack on trace A.*

Command Examples

Absolute level:
TA:DEF EQN,"JITTERW(C2)",SLOPE,POS,LEVEL,213.9E-3,HYST,0.5

Relative level:
TA:DEF EQN,"JITTERW (C2)",SLOPE,POS,LEVEL,42 PCT,HYST,0.5

Query/Response Examples TA:DEF? returns:

Absolute level:
TA:DEF EQN,"JITTERW (C2)",SLOPE,POS,LEVEL,213.9E-3 **V**,HYST,0.5

Relative level:
TA:DEF EQN,"JITTERW (C2)",SLOPE,POS,LEVEL,42 PCT,HYST,0.5

PERHIST

<function>:DEFine EQN,"PERHIST(<source>)", SL_DIR,<dir_value>, SL_CENTER, <center_value>, SL_WIDTH, <width_value>

Where:		
	<source>:=	{C1, C2, C3ⓓ,C4ⓓ,TA, TB, TC, TD}
	<function>: =	{TA, TB, TC, TD}
	<dir_value> : =	{V, H}
	<center_value> : =	-4.00 to 4.00 DIV
	<width_value> : =	1 to 255 bins for horizontal slices, or 1 to 999 pixels for vertical slices.

Command Examples

Horizontal Slice:
TA:DEF EQN,"PERHIST(C2)",SL_DIR,H,SL_CENTER,-0.62 DIV,SL_WIDTH,34

Vertical Slice:
TA:DEF EQN,"PERHIST(C2)",SL_DIR,V,SL_CENTER,-0.62 DIV,SL_WIDTH,34

Query/Response Examples TA:DEF? returns:

Horizontal Slice:
TA:DEF EQN,'PERHIST(C2)",SL_DIR,H,SL_CENTER,-0.62 DIV,SL_WIDTH,34

Vertical Slice:
TA:DEF EQN,'PERHIST(C2)",SL_DIR,V,SL_CENTER,-0.62 DIV,SL_WIDTH,34

PERTRACE (Average)

<function>:DEF EQN,"PERTRACE(<source>)",PTR_TYPE,AVG

Where:

<source>: =	{C1, C2, C3☝,C4☝,TA, TB, TC, TD}
<function>:=	{TA, TB, TC, TD}
<sigma_value> : =	0.5 to 10.0
<pop_value> : =	0.5 to 100.0 PCT

Command Example

TD:DEF EQN,"PERTRACE(C2)",PTR_TYPE,AVG

Query/Response Example TA:DEF? returns:

TD:DEF EQN,"PERTRACE(C2)",PTR_TYPE,AVG

PERTRACE (Sigma)

<function>:DEF EQN,"PERTRACE(<source>)",PTR_TYPE,SIGMA,SIGMA_FACT,<sigma_value>

Where:

<source>: =	{C1, C2, C3[e],C4[e],TA, TB, TC, TD}
<function>:=	{TA, TB, TC, TD}
<sigma_value> : =	0.5 to 10.0
<pop_value> : =	0.5 to 100.0 PCT

Command Example

TD:DEF EQN,"PERTRACE(C2)",PTR_TYPE,SIGMA,SIGMA_FACT,1.5

Query/Response Example TA:DEF? returns:

TD:DEF EQN,"PERTRACE(C2)",PTR_TYPE,SIGMA,SIGMA_FACT,1.5

PERTRACE (Range)

<function>:DEF EQN,"PERTRACE(<source>)",PTR_TYPE,RANGE,RANGE_POP,<pop_value>

Where:

<source>: =	{C1, C2, C3☝,C4☝,TA, TB, TC, TD}
<function>:=	{TA, TB, TC, TD}
<sigma_value> : =	0.5 to 10.0
<pop_value> : =	0.5 to 100.0 PCT

Command Example

TD:DEF EQN,"PERTRACE(C2)",PTR_TYPE,RANGE,RANGE_POP,99.5 PCT

Query/Response Example TA:DEF? returns:

TD:DEF EQN,"PERTRACE(C2)",PTR_TYPE,RANGE,RANGE_POP,99.5 PCT

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